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1953 - 1954

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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 900 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

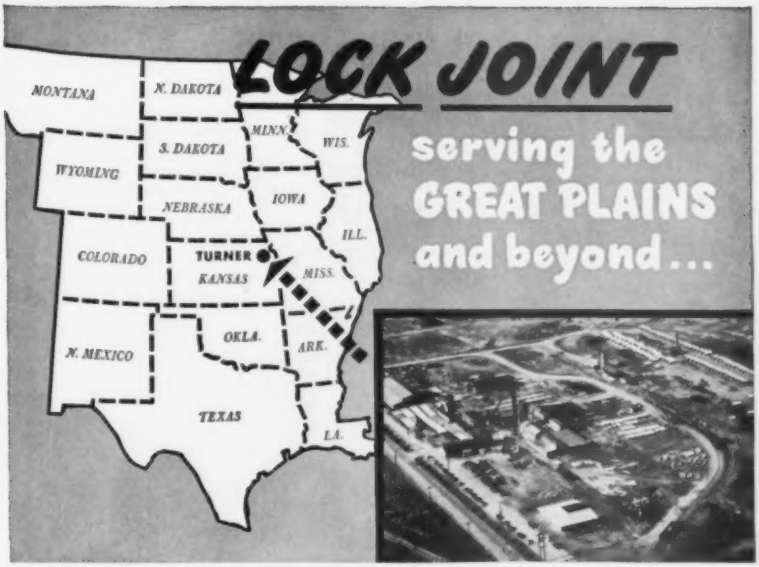
An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees		*Annual Dues*
Members	$ 5.00	Members	$ 6.00
Juniors	1.00	Juniors	3.00
Associates	10.00	Associates	20.00
Corporate Members	10.00	Corporate Members	10.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September or October on such date as the Executive Committee may designate.



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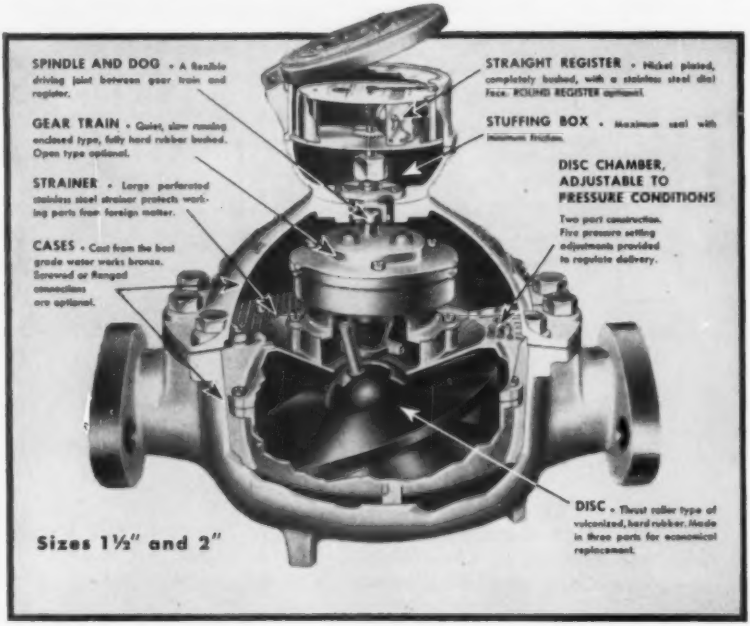
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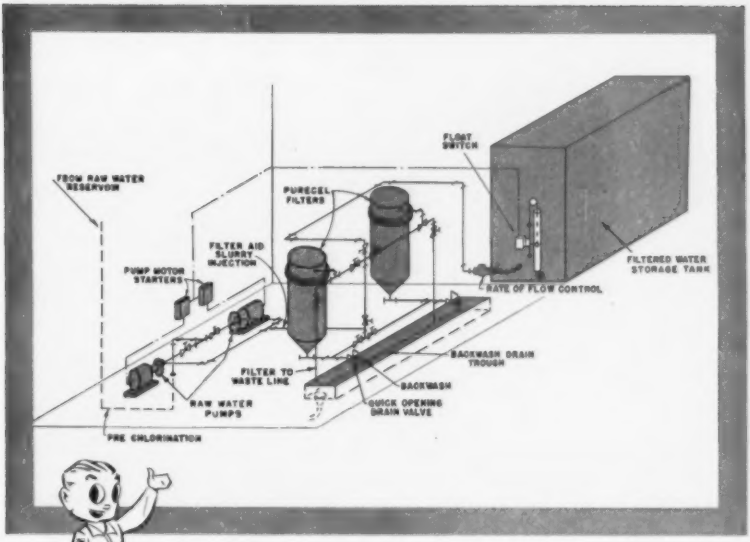

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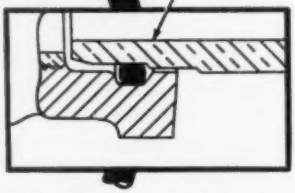

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44

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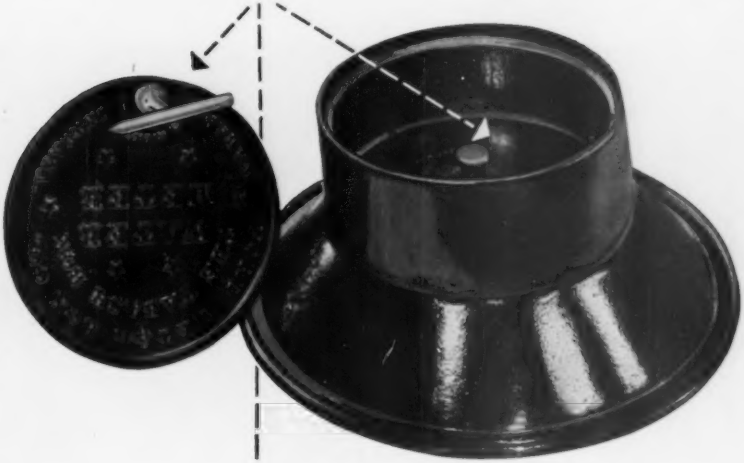

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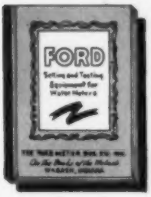

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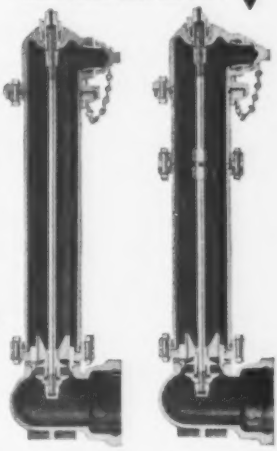

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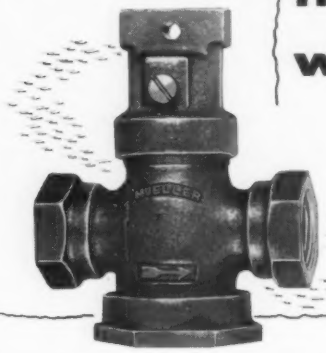

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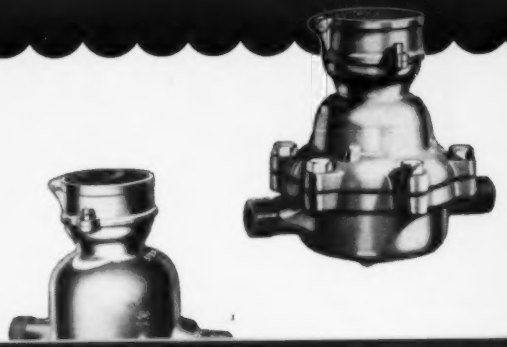

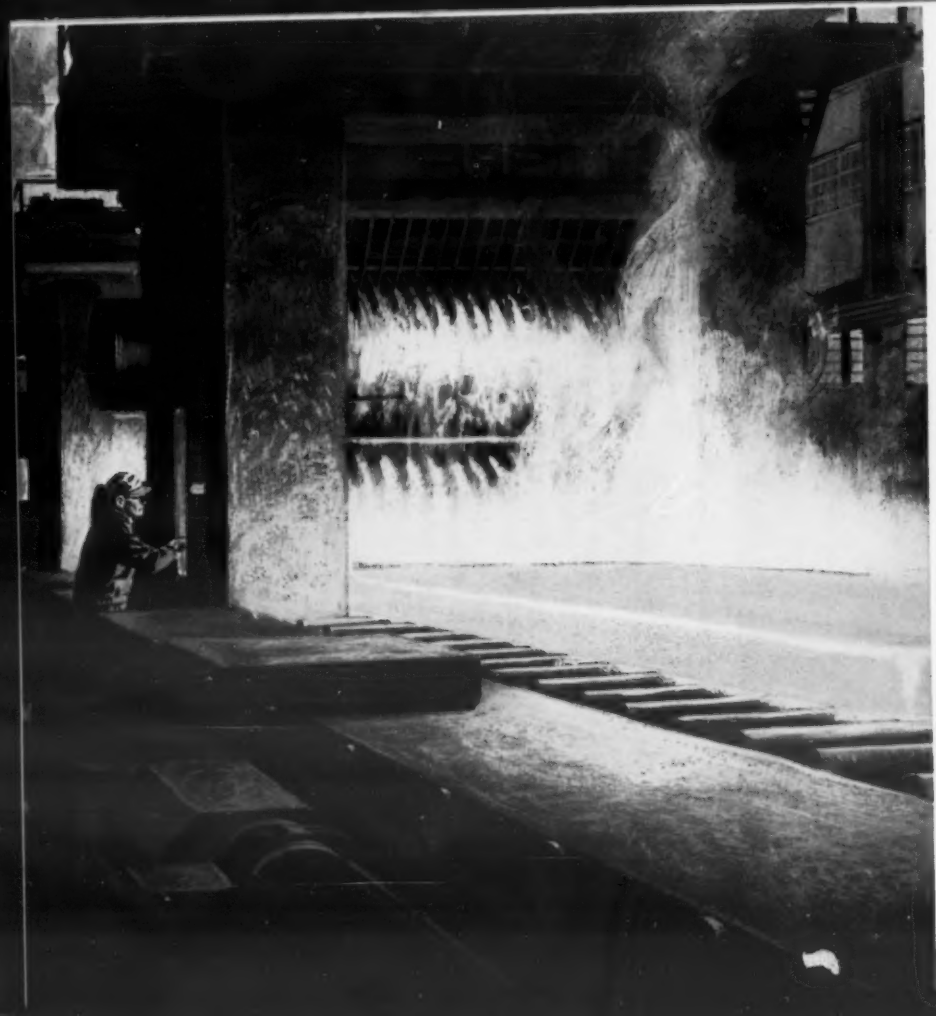

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"Measures the water of the world"

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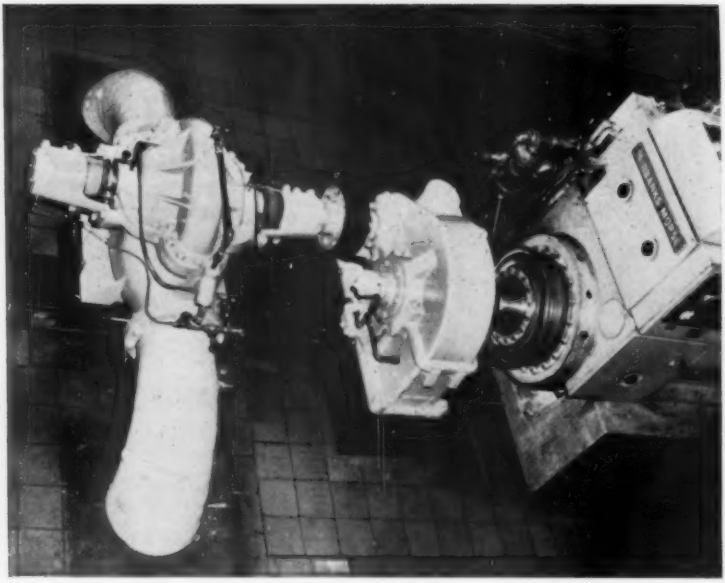

12″x14″ Fairbanks, Morse Figure 5814 Pumps

Pictured above is a bird's eye view of one of the two 12″ x 14″ Fairbanks, Morse Figure 5814 Double Suction Horizontal Split Case Centrifugal Pumps, supplying the Arlington, Arlington Heights and Belmont sections of the Metropolitan District Commission's Water Division.

Each of these two pumps rated at 6000 G.P.M. at 220 TDH is driven by an eight cylinder Model 31A8½ Fairbanks, Morse Diesel Engine.

Installed in early 1953 as part of the MDC's new expansion program, both pumps take suction from the Wachusett Reservoir, Clinton, Massachusetts, distributing main and boost the pressure in the area served.

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NOW WITH THE RING-TITE COUPLING

NEW

- in design
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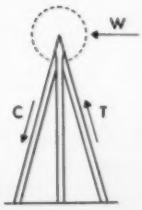
for modern water storage

THE

PITTSBURGH •DES MOINES Tripod-Sphere

PATENT APPLIED FOR

The TRIPOD-SPHERE illustrated, located at Gonzales, California, has 100,000-gallon capacity, with 31 ft sphere, on a 100 ft tower. Head range is 23 ft 1 in. Diagram shows how wind force (W) on sphere places columns in tension or compression, without bending.



This remarkable Pittsburgh-Des Moines development in elevated water storage combines striking appearance with new construction simplicity and economy. • Consisting of an Icosasphere supported by a tubular tripod, the TRIPOD-SPHERE requires no wind bracing members. Because the center of wind pressure on the sphere coincides with the point of intersection of the supporting columns, no bending is introduced. Construction of the TRIPOD-SPHERE is covered by a patent application. • Write for details on this new design in terms of your prospective water storage needs.

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Best quality asbestos rope, brass caps attached to each end. Equipped with clamps.

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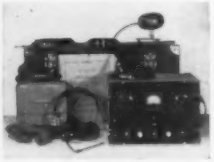
A light cast iron fitting with bell end for connecting house service with main sewer pipe without necessity for placing a Y-branch or T-branch in the sewer line.



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For water mains up to 12". Strong leather bag. Keeps the right tool for every job within easy reach.

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Inexpensive way of cutting pipe. Every wheel in contact with the pipe is a cutting disc, so cutter need be moved only a short distance to cut entirely around the pipe.

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New England Water Works Association
ORGANIZED 1882

VOL. LXVIII SEPTEMBER, 1954 NO. 3

This Association, as a body, is not responsible for the statements or opinions of any of its members

PORTLAND'S NEW SEBAGO LAKE INTAKE AND SUPPLY CONDUIT

BY HERMAN BURGI, JR.*

[*Read September 28, 1953.*]

In a paper† before the New England Water Works Association in Boston in September, 1951, the author stated that the Portland Water District was proceeding with a second intake and conduit to bypass its intake built in 1925. Here is the story of "Portland's New Sebago Lake Intake and Supply Conduit".

In November of 1950 a hunter reported noticing running water in the area of the Portland Water District's 54″ intake and conduit, constructed in 1925. We inspected, surveyed the location of the conduit, and found water coming from Station 21 + 00, the end of the 60″ tunnel from the lake and the beginning of the 54″ conduit towards the transmission line header at the chlorine house. Then to make sure this water was coming from our intake, Harold Scales, chemist for the Portland Water District, had soda ash fed into the intake screen chamber, starting at a definite time and continuing for 20 minutes, while he himself sampled water at the leak. He noted increased pH about 20 min after the starting time, which pH increased to a maximum, held about 10 min, and then dropped off. As a check, another and heavier dosing was ordered, and the result repeated, except that this time the pH went beyond the scale of the indicator and then dropped off. Thus the soda ash fed in at the intake chamber dosed the water in the tunnel and showed up in the leak.

Knowledge of this leak was quite important, because this 1925 intake was the only means of getting water from Sebago Lake to the transmission lines, and every drop of water used in metropolitan Port-

* Treasurer and General Manager, Portland Water District, 16 Casco St., Portland 2, Me.

† This JOURNAL, 66:3, 245, Sept., 1952.

land had to come from the lake. Available local storage could not take care of the demand.

During 1949 and 1950, the District had experienced repeated peak-load rates of 37 mgd, lasting through the daylight hours, with normal, average, daytime loads at a rate of 24 to 28 mgd. With such demands it was unwise to take the chance of unwatering the conduit and tunnel for an inspection, because the shut-down, unwatering and refilling would have taken better than 12 hours, and metropolitan Portland would have been out of water.

Naturally, the first question was: How about using the original conduit, replaced in 1925 by the one now leaking? This conduit was built in 1868 from "The Point" at Chadbourne's Landing, Standish, along a low run through the ledge ridge at the lake, to a point 5,400 ft away, where a 20″ pipeline was started for Portland. Construction was by open cut in earth and rock down 18 to 30 ft, except at two points, where, because of the depth of cut and hard ledge, tunnels were driven, one 741 ft and the other 30 ft long. The conduit had a brick bottom, two to four feet wide, vertical brick side-walls, and an arched brick roof, giving 3½ to 5 ft of head-room. It was laid level, but gave capacity trouble, so that in 1878, from a point 2,300 ft distant from the lake, it was rebuilt by dropping it 18 in. in the ledge for a distance of about 1,600 ft towards Portland and continuing in dirt from there to the 20″ pipe.

At the high lake levels its capacity was 14 to 18 mgd, and at the 1950 level of the lake its capacity was 6 to 9 mgd. The question was: Could we pump water through it to supply the 24- to 28-mgd daytime rate for Portland?

Two Portland Water District employees, J. Porter Hennings and E. Boyd Livesay, went through the conduit. They reported infiltration of ground water, the heaving of the brick bottom, and the dropping of the center of the arch in several areas. From their reports we felt that it was not safe to depend on this conduit to furnish the water supply to Portland by booster pumping while making repairs to the 1925 intake. (Repairs actually took four months.)

However, all of this gave us the idea of constructing in this 1868 location for a 60″ intake out into the lake, utilizing the ledge cuts for a conduit to the take-off of the 1868 20-inch main to Portland and the start of a 30″ and a 42″ main leading to the chlorine station. We

took this idea to Metcalf & Eddy, who were the designers of the 1925 conduit, and they in turn called in Karl R. Kennison to figure on the hydraulics.

Mr. Kennison shortly came back with a report, showing that hydraulically this was safe and sound, and suggested proceeding. This question of the new intake and the use of the siphon was brought before the Trustees with an estimate of $1,000,000 as the cost and, after discussion, they authorized the plans to be prepared and construction to proceed. Mr. Kennison in the meantime had worked further on the hydraulics, but was not in a position to do the detail drawings. We therefore hired Camp, Dresser & McKee of Boston, and Thomas R. Camp with Mr. Kennison finally evolved the present scheme of the siphon. Herman Dresser of that firm did the actual design, specifications and details of the layout.

In the meantime, it was necessary for the Portland Water District to gather data. We made a complete survey of the old conduit, getting its lines and grades, and at the same time, by going through the old conduit and making soundings through the bottom of it, we were able to establish the ledge line along the conduit. We also had drilling crews making soundings and borings along the 1868 conduit and prospecting for the best location for a screen chamber. From this screen-chamber location we had a crew out on the ice in January and February of 1951, making soundings in order to determine the direction and location of a 60″ intake pipe out in the lake.

Sebago Lake, the source of supply for the Portland Water District's system, has 45 sq mi of area and a drainage area of 425 sq mi, is approximately 16 miles from Portland's City Hall, and has sufficient elevation to give gravity flow. Records show the high lake level at 269 ft and the average low level at 257.7. The failure of the Eel-Weir Dam of the S. D. Warren Co. on the Presumpscot River could lower the lake to 253, and this elevation was recognized in the design.

All of these things finally were put together and led to five items of the lay-out (see Fig. 1) as follows:

1. *The Screen Chamber.*

The screen chamber is an eight-sided structure, 53 ft by 32½ ft in plan and 28½ ft deep from the operating floor, elevation 270.5, to the bottom. It contains an entrance bay connected to three screen

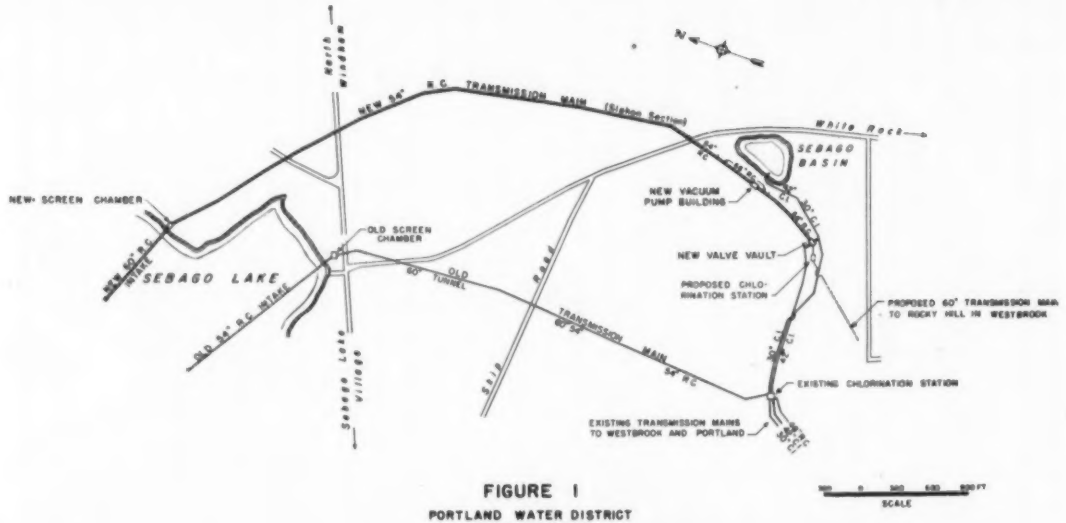


FIGURE I

PORTLAND WATER DISTRICT
PORTLAND, MAINE
NEW INTAKE AND AQUEDUCT AT SEBAGO LAKE
TRANSMISSION MAINS TO EXISTING CHLORINATION STATION

pits, each of which has a sluice gate at each end. Each pit has a Link-Belt traveling screen and a hand screen in series, and these connect to another bay from which the 54″ conduit takes the water. The water will flow into this last chamber by gravity, even at what we consider low-low water in the lake. Since we were constructing a siphon to avoid ledge excavation, we needed a rise of elevation in the lead away from this screen chamber, and it saved money to build into this screen chamber a vertical vacuum riser to the 255-foot elevation of the 54″. This was done by a curtain wall, extending down to within 6½ ft of the bottom.

The screen-chamber construction began in May of 1951, by building a dike around the location, driving sheet-pile cofferdam and excavating the earth, as well as about 500 cu yd of ledge.

Thereafter, the reinforced bottom floor, walls and operating floor were constructed, and this was finished in December, 1951. In 1952 the brick superstructure was erected; also two 60″-wide Link-Belt screens, hand screens, and the necessary piping were installed.

2. *The 60″ Intake.*

Eight hundred feet out in the lake a pile structure was built, upon which was formed and cast a concrete intake fixture, designed as an elbow, having a horizontal opening 10 ft long by 5 ft wide and 5 ft deep inside, to allow for the connection of the 60″ pipe (see Fig. 2). After being cast, the fixture was lowered into the lake, resting on piles, such that the top or inlet of this subaqueous elbow fixture was set at an elevation of 238.03 ft, or 4 ft above the normal bottom. The pipe is a 60″ Lock Joint subaqueous pipe, 16 ft long, with rubber rings and pull-up bolts on each side. The pipe was lowered into a previously prepared trench, joined together by two divers, and laid to instrument grade. Upon arrival of the pipe within four lengths of the screen chamber, we inserted a special length, fitted with a collapsible steel bulkhead on the inside, and this pipe was placed and concrete tremied around the whole length of the pipe, and a cofferdam built over it. This unit, with the bulkhead and the cofferdam, kept out the lake water, and the contractor could excavate in the dry on the inside of the cofferdam and place the rest of the 60″ pipe and the closure to the screen chamber in the dry. A profile of the intake pipe is shown on Fig. 3.

FIG. 2.—SUBAQUEOUS INTAKE FIXTURE READY FOR LOWERING ONTO PILES IN THE LAKE.

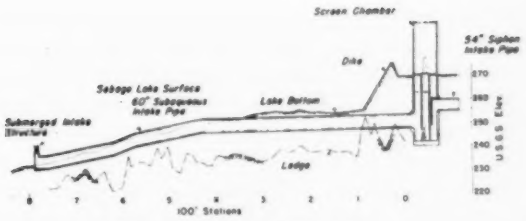
3. *The Conduit from the Screen Chamber to the Point of Connection with the Existing System to Operate as a Siphon.*

Now why a siphon?

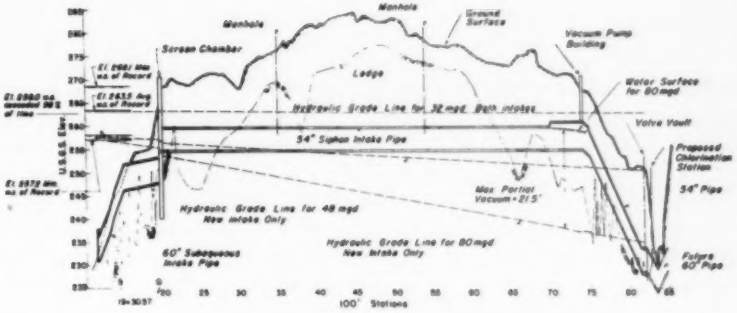
As a pressure pipe it would have meant tunneling through 4,000 ft of rock, which, from the 1925 tunnel experience, is seamy and unreliable rock with water troubles. To follow the hydraulic grade with open cut would have required a sloping trench, 20 ft deep at the start and 40 ft deep at the Vacuum Building, and would have necessitated the removal of better than 20,000 cu yd of ledge.

Mr. Kennison and Mr. Camp agreed with the author that the Portland Water District could safely construct the conduit as a siphon at a saving of probably a half million dollars.

Therefore, the decision was made to run a 54″ conduit level through the 1868 cut to the end of the old conduit, and there we could, in a distance of 782 ft, drop 26.25 ft to give us the downstream leg of the siphon. The elevation of 255 for the invert was chosen as representing the lowest level with the least amount of bottom-ledge removal. We installed 54″ Lock Joint pipe, bar type, in 16-foot lengths, designed for 22-in. vacuum and 20 ft of cover over it. The 54″ size



PROFILE OF SUBAQUEOUS INTAKE PIPE



HYDRAULIC PROFILE

FIG. 3.—PROFILES OF NEW SEBAGO LAKE SIPHON INTAKE.

was chosen on Mr. Kennison's advice, as in a siphon it is desirable to have velocity, in order to scrub the air along with the water and minimize the chances of air binding.

For air removal, 480 ft of 66″ pipe were inserted at invert elevation 255, just ahead of the down leg, or discharge leg, of the siphon at Station 74 + 06.95, which would give a 12″ air chamber on top, from which by vacuum pump air could be exhausted, so as to maintain a full 54″ pipe.

The contractor used a 2½-yard Northwest backhoe or drag line. He first removed the 741- and 30-foot tunnel sections by drilling and blowing in two levels, leaving a third level until he came along with the pipe laying. Then he started at the valve-chamber end, since that would be laying pipe uphill. Here he found the worst conditions of

soft, wet clay with horizontal, water-bearing sand layers. After excavation, he placed 12 to 18 in. of crushed rock and sand mix to grade, placed the pipe, and then tamped sand and gravel around the pipe up to the spring line. Thereafter, sand was put in to cover the top of the pipe and several feet of spoil were added to hold the pipe down.

Backfilling was in three stages—first the initial fill, and after several weeks the bulldozing of about another 10 ft of fill, and again in October backfilling to the top. This, with the rain of 1951, gave good compacting of the fill.

In following the line of the old conduit, we dug it out and were surprised at the good brick-work. In places we even had to use dynamite to break it apart. Of course, our pipe level was about the level of the bottom of the conduit, and therefore this bottom had to be taken out. At the same time we also found wood sheeting, used during the construction of the 1868 conduit, in very fine condition, good and sound. As we approached the ledge ridge, we got into the open ledge cut and naturally followed it. The contractor at times had to trim off the sides of the rock cut, in order to get sufficient room, and at other times, where he found a high spot in the bottom, he had to take it out, as the specifications called for a clearance of at least 6 in. between ledge and pipe. On top of the ledge a combination of sand and crushed rock was put in as a bed and the pipe laid on top of this to grade, and then again backfilled with sand on the sides and top. Later the spoil was put on, except for very large rocks.

In the ledge cut the contractor used the Northwest as a drag line, trenching out the fill and blown rock. He used a tractor crane on the side of the ditch to place the gravel; then the pipe to instrument grade; then the sand for tamping to the spring line; and sand cover over the pipe. While again trenching with the drag line, the crane continued with backfill.

He ran into the trouble of getting the water out of the trench and had to use the Portland Water District's Moretrench jet pump down in the trench on top of the laid pipe, to force the water over the sides of the trench.

At one time the contractor had just finished laying six lengths of pipe when a very heavy shower came up in the evening. The next morning he found this 54″ pipe floating. He generally closed the end

of the pipe with a steel plug and did not have time to backfill on top of the pipe. The rain water going into the trench floated the pipe up, and he had to re-lay this pipe the next day. Thereafter the contractor was very careful to get about four feet of backfill on top of his pipe after laying.

There were delays due to the wet 1951, and the job was stopped 2,000 ft shy of finishing in November of 1951. The contractor had to come back in 1952 and made his closure with the screen chamber on July 3, 1952 (see Fig. 4). We salvaged 11,764 yd of ledge cut made in 1868 and 1878 by rebuilding in this location.

FIG. 4.—CLOSING PIECE OF 54-INCH CONDUIT TO SCREEN CHAMBER.

4. *The Vacuum Building.*

The vacuum building has a basement and a sub-basement. The 66″ pipe goes through the sub-basement, and from this pipe a vertical 24″-tee connection allows for a 12″ riser, similar to a barometric condenser leg coming back to a header, onto which are connected vacuum pumps. Electrical control was installed, using floater arrangements to maintain the water level in the 66″ pipe, so as to have approximately a 6″ air space as a minimum and a maximum of a 12″ air space at the top of the pipe. The level of the floats would determine which vacuum pump would run to evacuate air. In this manner we proposed to maintain the vacuum condition necessary in order to flow water through this 54″ conduit as a siphon.

Two to four feet of concrete fill on top of ledge formed the floor of the second basement, on which the 66″ pipe rested. The substructure was finished in the fall of 1951 and the superstructure was built under a tarpaulin house during December, 1951, and January and February, 1952. This allowed for the installation of the piping, fittings, pump, and electrical work during the spring of 1952.

5. *The Valve Chamber.*

The valve chamber is a 26′ x 26′ concrete vault to house the valves controlling the 54″ conduit and 30″ and 42″ tie lines from this location to the chlorine house.

The pipe-laying contractor started the 54″ conduit one pipe length away from the valve chamber. Another contractor took care of the construction of the valve-vault foundation, which had to be taken out of ledge. Thereafter the pipe-laying contractor came back and installed the pipe, the 54″ x 48″ reducer, a 48″ x 48″ x 36″ x 24″ cross, and fittings, together with the valves (see Fig. 5). On the 48″ run two 48″ valves were installed, one on the lake side of the cross and the other on the Portland side of the cross. This Portland-side valve will at a future date control a line going through a Venturi meter and chemical control house, and feeding a 60″ line going to Portland. On the left-hand side of the cross facing Portland, a 24″ valve was installed and that was connected to the 30″ cast-iron pipe installed in 1902. On the right-hand side of the cross a 36″ valve supplied a 42″ pipe, leading to the 42″ installed in 1912. These 30″ and 42″ pipes

feed into the header at the chlorine house, 2,000 ft away, putting water into the transmission mains.

FIG. 5.—VALVE INSTALLATION AT PORTLAND END OF 54-INCH CONDUIT.

After the pipe contractor finished the fittings and valve arrangement inside of the valve-vault foundation, the building contractor constructed the sidewalls and roof during November, December and January, as we desired to have this equipment housed, to prevent damage to these large valves. He had to build his structure underneath a tarpaulin house. This valve vault was designed to have three feet of dirt on top of the roof, so that the valve house need not be heated. It has a small sentry type of entrance leading down into the vault.

Testing.

At the end of July, 1952, we were ready to begin filling the conduit and testing. First, water was pumped into the forebay, to allow for adjusting and testing the sluice gates. Then we tested the Link-Belt screens.

After that we were ready to open the screen chamber to the lake water, and on August 4, 1952, the 2″ bypass valve in the steel bulkhead of one of the 60″ intake pipes was opened and flooded the forebay

to lake level. On August 6, a diver went down in the forebay and removed the bolts, braces and gaskets, and by tilting could remove the 59-in. steel bulkhead plate, to allow the full 60-in. opening to the lake.

With sluice-gate control, we were able to allow a flow of about 12-in. depth through the 54″ conduit to a blow-off at the valve chamber, to wash out the pipe. Thereafter, we allowed the conduit to stand under lake pressure for several weeks, as further curing and sealing of the conduit, maintaining a flow by partially opening the blow-off.

We had adjustments to make on the Link-Belt screens and then we were ready to test.

Vacuum Test.

The maximum vacuum head available was brought about by holding the screen chamber backbay at elevation 251 ±, while holding the water level at vacuum building in the 54″ conduit at 260.44, and thus creating a difference of 9.4 ft or 8.3 in. of mercury. We held this for several hours.

To make sure that air could enter the 6,000 ft of 54″ pipe, we next drew the water down to 257.75 ft of elevation, or 2¾ ft of water inside the 4¼-ft diameter of the 54″, thus exposing the upper half of the conduit to air. The afterbay water level was at 250.99, or a difference of 6.67 ft or 6 in. of mercury, which level we held for 12 hours.

Priming Test.

An important operational test was to see if we could start this conduit flowing, should the conduit have been out of operation and the lake be at its low level of 257.7. We made this test by first creating a water level of 257.5 throughout the conduit and in the afterbay at the screen chamber. We then started the vacuum pumps. These pumps withdrew air from the conduit and in so doing raised the water within the conduit. This water had to be supplied through the sluice gates, by allowing water to go into the afterbay but still maintaining the level in this afterbay below 257.7. After an hour and 20 minutes, one pump shut down because the water level had reached its float control, and four minutes later the second pump shut down with the conduit full of water. Thereafter we opened the blow-off valve at the valve chamber, to make the water flow, and it did flow from a level of about 255 in the

afterbay and through the conduit, maintaining its own vacuum of 4 in. We therefore successfully primed the siphon and made it operate.

Final Connections.

After this we had several valves to install and connections to make, to cut the 30″ and 42″ pipes to the chlorine house, so as to cause water from this new 1951 intake to flow through the master meter at the chlorine house. On October 1, 1952, we first turned water from the lake through this new intake into the Portland Water District's system. For three days we ran the two intakes in parallel and thereafter shut down the 1925 intake, and from then until July 8, 1953, this conduit carried the full demand of the Portland system, including the maximum load ever experienced—a rate of 40.5 mgd on July 7, 1953. The only drawback is the 2,000-ft tie feed between the valve chamber of the new intake and the transmission header at the chlorine house, with one 42″ supplying a 42″ transmission line and one 30″ supplying a 48″ transmission line. We had a loss of about 3½ lb in this 2,000-ft line. At some future date this will be corrected by the construction of a new 60″ transmission line to Portland, fed directly from this conduit, in which case the tie lines can be shut off and the two systems will feed independently, but in parallel, and will join by a tie line at the Portland-Westbrook boundary.

It is interesting to note the change of the pressure-vacuum relations in the operation of the siphon at the vacuum building by following the 40-mgd rate through the steps of varying lake levels:

Flow rate (mgd)	*Lake elevation*	*Pressure or vacuum (ft)*
40	268.7 (high lake)	4.5 (pressure)
	263.5 (average)	1.0 (vacuum)
	257.7 (normal low)	6.5 (vacuum)
60	257.7 (normal low)	13.0 (vacuum)

MINERAL CHARACTERISTICS OF MAINE PUBLIC WATER SUPPLIES

BY RAEBURN W. MACDONALD*

[*Read September 28, 1953.*]

The minerals of Maine have throughout the state's history interested a great many people in various stations of life, from the Indian, through the colonial and nineteenth century miners down to the prospector and hobbyist of today. While the water chemist is not represented in any of these groups, even though it could be said he is often searching for minerals, it is perhaps fitting that he does not fall into these categories, for he rather hopes he will not find an appreciable quantity of mineral, an attitude contrary to that of the other group.

From the standpoint of the hobby group, who are for the most part, at least to some degree, students of geology and are searching for surface deposits, regardless of ore quality, to provide specimens only, the entire state proves very interesting. The hobbyists' supporting data, besides a knowledge of geology, are the experience of commercial miners in the region, detailed geological and topographic maps, and perhaps the most vague, but most romantic, source of information, consisting of legends, which are innumerable. Most of them stem from the days when the Indian, having come into possession of firearms, found himself in need of bullet metal and, forced to provide his own, located deposits of ore from which he could extract lead over a wood fire, and the legends always provide fabulous percentages of silver. Such are the stories that have started hunts for, among others, the mine on Olamon Stream, which, according to legend, provided lead for Baron De Castin and his Tarratines; the "fishing brook" mine near Hartland; and the lead mine in Aroostook County, possibly at Musquacook Mountain, from which, tradition says, the United States troops and the Maine Militia during the Aroostook War were supplied with lead, regardless of the diverse opinion of some cynics that the red men

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traded with the British troops in New Brunswick to obtain the metal and simply resold to the American garrison. Legends of gold strikes are similar, but less frequent, and iron appears scarcely at all.

Those interested commercially have recently done some exploration in parts of Maine, notably in Aroostook County by the Bureau of Mines, and other groups have had another look at Katahdin Iron Works and the lead mines of Washington County. In the past, the mines never were get-rich-quick projects for their owners, but they were paying businesses over a period of time. The era immediately following the Civil War was especially prolific in such mining, as the shortages were great and the large desposits in the west were not yet open.

The water chemists' entrance to the field is comparatively new. It is of course unnecesary to point out, especially to this gathering, the vast dissimilarity of these prospectors to the chemist dealing with water-supply problems. Even the incentive is different and, if there is anything in common, it is the simple truth that each keeps in the back of his mind certain geological facts that pertain locally. Most of the water supplies within the state have not shown a degree of mineralization before entrance to pipelines which justifies or requires treatment to rectify. The bulk of the exceptions occurs in comparatively small supplies, where, up to the present time, finances have not made possible much treatment to improve water quality. Of the damage occurring from mineralization, that done by water hardness unquestionably takes first place. In view of the foregoing, the work of the water chemists to date has been more or less on a basis of collection of information, rather than planning and execution of treatment.

However, since this is a meeting of the water-supply fraternity, we should stay closer to the water-supply field and confine ourselves to the identification of minerals which predominate in the surface and ground waters of Maine, as indicated by the analysis of drinking-water samples. From the results, for purposes of this paper, median figures have been generally selected and, as in all work of this sort, more information would be desirable, but in only one or two cases is there an actual shortage of data and certainly enough exist to define water quality as to domestic supply desirability and industrial utility.

In discussing the chemical quality of waters, the terms "large

quantity" or "small quantity" are used on a state-wide basis of comparison only. For the benefit of those unfamiliar with the use of median values, they are the values in a series which have an equal number of higher values and of lower values in the series. They are often used in work of this sort rather than averages, as they are not so much affected by one out-of-line quantity. Generally speaking also, the values used are from public water-supply analyses, since, except under special circumstances, private supplies are not subject to complete mineral investigation.

The geology, geography and other factors affecting water quality differ enough from one section of Maine to another so that a generalization on a state-wide basis would be rather confusing. Accordingly the geology of water supply will be viewed section by section. These sections, as they will be considered, can, for convenience, be defined by the following geographical areas: the Aroostook Watershed, which takes in the valley of the St. John River and its tributaries, and is so called because Aroostook County comprises the bulk of the area; the Coastal Section, which includes the area paralleling the coast to a depth of 30 to 50 miles and much of the basin of the St. Croix River; and the Interior Section, which comprises the drainage basin of the Penobscot River, the Kennebec, Androscoggin and Saco River drainages, excluding the coastal belt previously described, these basins being combined and discussed as one, as the geographical and water-quality facts in respect to this paper seem to dictate.

First, let us look at the northernmost section, the inhabited portion of which lies chiefly in Aroostook County. This region is basically a rather flat plateau, relieved by river courses, such as the St. John and the Aroostook, and by an occasional sharp elevation of volcanic origin. The generally flat topography has created many bogs and cedar swamps, which have the usual effect on the water quality of many of the county's streams. The geological formations are, for the most part, limestones, slates and shales, overburdened with glacial drifts and clays. This bedrock is compact, in the case of slates and shales fine-fissured, and is a poor yielder of water; hence the greater portion of the supplies is drawn from surface waters. Characteristically, the ground waters of this area are harder and more highly mineralized than surface waters. The outstandingly mineral-bearing area of the region

is the hematite area, roughly in the Presque Isle-Limestone-Fort Fairfield triangle, where the content of magnesium and calcium is exceptionally high, as Maine waters go. Hardness of water in this area runs well above that to be expected in any other region.

The ground water of the Aroostook region is high in calcium and magnesium, the average calcium content for the county being about 38 ppm against 8 ppm for the state at large, while the high for the region is 64 ppm against a general maximum of 32 ppm; the magnesium median for Aroostook is 11.5 ppm compared to a 1.6 median for the state, with a regional high of 15 ppm. The average sulfates are about four times as high, at 32 ppm with a maximum of 47 ppm, in Aroostook as in the remainder of the state, and the chlorides three times as high with 9.0 ppm median and 17.0 ppm maximum. That nitrates are present in approximately the same average value for this area as a whole as for the entire state will come as a surprise to many, who are well aware that many wells in Aroostook are exceedingly high in nitrates, due to percolation of surface water carrying local contamination from fertilization. There is little or no evidence of fossil nitrates presented by examinations. This fertilization is also, no doubt, the cause of high chlorides, although this could also be due to presence of chlorite schist in some areas. Other minerals fall moderately below the state average or median in quantity present in the water.

In surface waters the ratios are similar. The Aroostook waters are harder—43 ppm to 18 ppm, with one source running to 156. Again the St. John Basin waters are well above the state median in content of calcium, magnesium, sulfates and chlorides. The calcium ratio is 19 ppm to 3 ppm, with 30 ppm a maximum, and that of chlorides is 4 ppm to 2 ppm, with a 17-ppm high. Nitrates have a similar story in surface water to that of ground water, except that the surface-water ratio to that of the remainder of the state is higher. On the basis of median figures, the surface-water ratio is 0.1 to 0.06 ppm and the ground-water figures are even up at 0.15 ppm, but the maximums in each case are somewhat different, with a 2.5 ppm to 0.30 ppm ratio in surface waters and a 3.0 ppm to 1.5 ppm ratio for ground waters. In considering these figures, it should be remembered that analyses of water supplies have been used for comparison, that these supplies ordinarily are purposely taken from areas of comparatively low cultiva-

tion, and that private wells, often necessarily in highly fertilized localities, run much higher in nitrates than these figures show. A study of this type of well, limited to the farming area of Aroostook, would also show the ratio of nitrates in their waters compared to the state at large much higher than that of these public supplies. Content of other minerals in St. John Basin waters is roughly similar to medians of Maine in general.

The other extreme from the St. John Basin, geography-wise, is the coastal belt, which can be considered as a strip parallel to the coast, about 40 miles wide. The eastern part of the region includes much of the area adjacent to the lower St. Croix. Geologically, most of this coastal belt had its origin as ocean bed, rising from the sea after the last glacial age, subsequently being cut and eroded by streams rising inland, until it is now a region of irregular topography with hills rising away from tide water and from the beds of major rivers. Bedrock formations are chiefly granite and stages of sedimentary rock. East of the Penobscot the region is still heavily forested, while the west side is somewhat more agriculturally developed and many areas support sizeable towns. There are many bogs along this coastal belt and, as a consequence, much of the surface water and some of the percolation water, at the start, are fairly aggressive.

However, the only two really outstanding positive features of both ground and surface water in the area are, as might be expected, the high content of chlorides and the high content of sodium, other minerals being present in only about normal quantities. The sodium median for the coastal area is 2.80 ppm and for the state in general, 1.6 ppm. Chlorides, in this case coming from marine sources, either ancient deposits or precipitated with rain from air currents, rather than from agricultural activity as in Aroostook, bear a 5.0 ppm to 2.2 ppm ratio for surface waters and a 6.0 ppm to 3.5 ppm ratio for ground water.

Here again it should be remembered that the statistics apply generally to public supplies only, as these are the only sources on which there are complete data. Chlorides, however, are established on all water samples coming into the laboratory and a great many private water supplies are found to run much higher in chlorides than the maximum in public supplies, represented by 17.0 ppm for ground

water and 17.0 ppm for surface supplies. Almost universally, as previously mentioned, these very high chlorides occur due to marine deposits, as this is an area which was once covered by salt water, gradually rising in elevation after being relieved of the weight of the ice sheet. High chlorides in surface supplies are due in part to occasional marine deposits which have been contacted, but mostly to winds, fogs and precipitation, moving in from the sea and depositing chlorides where they reach water supplies.

Perhaps the strangest feature of the waters of this coastal belt is the failure of those from east of the Penobscot to show any more lead than other areas of Maine, when the mineralization of the area is predominantly lead-silver pyrites, these compounds being not only predominant but in heavy concentrations. Lead with silver as a by-product has been mined at many places throughout the eastern area, among them Cooper, Lubec, Cherryfield, Sullivan, Blue Hill, Goulds-boro and Harrington.

Probably a predominant factor in this relation is chance and the fact that most wells are isolated from heavy lead-bearing points. It might be added that most of the known heavy concentrations of lead ore have been fairly shallow and that here again the concern is with public supplies, private supplies not being examined to reveal this type of lead.

The remaining area, the interior, comprises the extreme upper Saco Basin, the upper Androscoggin, Kennebec, Penobscot and St. Croix Basins above the coastal belt, thus forming a roughly triangular area, including, approximately, the counties of Oxford, Franklin, Somerset, Androscoggin, Kennebec, Piscataquis and Penobscot. In this area the western portion is predominantly of granite bedrock, with an over-burden of gravel and sand with some glacial till, while from the east the mother rock of the Aroostook region and of New Brunswick—shales, slates and schists—extends westward to meet the granites. Topography-wise, a comparatively high region of considerable relief tapers from the northwest into a region of fairly uniform topography, interspersed with low rolling hills. Natural waters of the region are soft and considered to be low in mineral content, when judged in comparison with other waters, but strike very close to a state median when only Maine is considered, the variation in general being only a small percentage of the median.

The most interesting feature of water analyses in this area is the mineral content of waters along the junction of metamorphized sedimentary with the igneous rock, which is more or less along a line wandering from near Merrymeeting Bay, north of Bath, northerly across the state, passing west of Moosehead. Such areas are notably rich in minerals and a tracing of high-mineral waters in this area will fairly well define the junction of rock types. With samples on each side of this strip running generally close to the median, a belt of specimens is found in which iron content runs up to 16 times as high as the median, with lead and copper showing a roughly corresponding ratio.

In one case, a supply coming from a semi-wilderness lake has an outstanding concentration of iron and lead, and an investigation of the mapping of underlying rock strata shows a joint between two rock ages, running through the lake. Many such conditions have turned up in regard to minerals—notably iron, which in certain combinations is well distributed, but its solubility depends much on water condition. Many of these mineralizations are easy to explain and in other cases the explanation is not readily apparent. In what is now the flowage of the Long Falls reservoir on Dead River, just above the village of Flagstaff, a tiny stream entering the river was always a characteristically ferric red and the natives explained it by saying the rust was from "one of Arnold's abandoned cannon," for this was along the route of Benedict Arnold's ill-fated march to Quebec.

Thus it appears that, except in the Aroostook area, where hardness causes considerable damage to water supplies and other mineralizations are responsible for some nuisances, together with some instances throughout the state where compounds of iron and coloring matter exist in water, the state is fairly fortunate in its available water supplies. There are also several instances, fairly well dispersed, of a rather high manganese-iron total. Their worst faults, however, are the highly corrosive nature of some of the surface waters prior to treatment and the fact that, for certain sensitive industrial uses, some of them are high in organic coloring. However, generally speaking, both the surface and ground waters are satisfactory for all ordinary domestic and industrial uses and, best of all, are present in great abundance.

MANUFACTURE OF PLASTIC PIPE

BY BRIGHAM BRITTON*

[*Presented Sept. 29, 1953.*]

The Carter Products Corp., now "Carlon", of which I was President, purchased the first plastic extrusion machine, to my knowledge, made as such in this country. It was purchased from the National Rubber Machinery Manufacturing Co. of Akron, Ohio, with the idea of making our fortunes in extruding plastic table edgings, to replace the shortage of aluminum edgings brought on by the advent of World War II.

We were the second people in the country to go into the commercial extrusion of thermo-plastic materials; the first being a company which made its own first machine. It is questionable which had the easier time, because nobody knew anything about the extrusion of plastics—a problem a great deal different from the extrusion of rubber materials, from which the technique was developed.

For the next five years, we learned as much as we could about the extrusion of plastic materials with varying success. Toward the close of the war, Carter Products accomplished something which had not been done heretofore—that is, running plastic tubing to close enough tolerances to have feasible commercial applications. We proceeded to do this in increasing proportions to other people's specifications. We, for instance, found ourselves making tubing for a chemical company to run corrosive liquids through, under which plastic would stand up and do a job that steel would not. We made a great many tubes for a plastic fly spray and we got into the manufacture of polyethylene film, mostly in tube form, which was widely used in the packaging industry.

In the year 1947, we heard that the soft-coal industry had a terrific problem in pumping water from their mines, in order to keep them from flooding. To me, an interesting figure is that for every ton of coal taken from the mines of this country, seven tons of water are

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pumped out. This piping of water from the coal mines had been for years a tremendous source of business for the manufacturers of steel pipe, because in a great percentage of coal mines the presence of sulphurous acid causes steel pipe to corrode out in a very short time. I have heard of an actual case where a miner dropped a monkey wrench in a pool of water in the mine and, when he came back for it several days later, nothing was left but the wooden handle.

It occurred to us that polyethylene, from which we were manufacturing sheet, might very easily go a long way toward solving the corrosion problem of pipe in the bituminous mines of this country. We therefore persuaded the Pittsburgh Consolidated Coal Co. to put 2,000 ft of polyethylene pipe in each of three mines, where they had an extremely bad sulphur condition. Last year the superintendent of the first mine, in which we put this pipe, told me that the original 2,000 ft were still there—5½ years later—and that he would have replaced steel pipe during that period at least ten times. The result was instantaneous. We found ourselves furnishing coiled pipe even in mines without a sulphur condition, because of its light weight, and because it could be easily and inexpensively installed in the narrow, winding corridors of coal mines.

We were in business to an extent of which we had never dreamed. Plastic pipe was in the coal mines to stay. Unfortunately for us, it stays too long, because, while there are many coal mines, it was not too long before we found that we ourselves and the many competitors who developed were literally putting plastic pipe (in our case, Carlon "E" pipe) in almost every mine in the country, and much of the same pipe that was put in during a period of three or four years is still there and will continue to be there for many years more. The few replacements necessary are caused by rock falls and the like, and the expansion of the mines themselves. This is, of course, a substantial business, but it does not annually begin to compare with the amount of steel pipe that was lost by the steel companies.

You will recall that in the late '40's both steel and copper were in terrifically short supply. This short supply gave us the opportunity more easily to get plastic pipe tried in farm water systems, for jet well installations and the accompanying water systems. The ease of laying, lack of scale and the corrosion-resistant capabilities of plastic

pipe were easily proved on their own merits, and we have heard some figures that today, on sizes under 2″, plastic pipe sales are accounting for 20% of the total pipe footage sold. This may account for the fact that one of the giants of the steel industry has recently acquired a small plastic-extrusion company and gone into the production of plastic pipe, a product at which they laughed five short years ago.

The extrusion of plastic pipe and plastics in general, after the bugs are once worked out, is a relatively simple operation. Plastic materials of the correct formulation and color are placed in a hopper, and plastic granules are fed by gravity into the plastic extruder, which is basically a steel cylinder, 2 to 6 ft long, with an inside diameter of one to ten inches. The cylinder is heated electrically, by steam or by oil to a temperature, depending upon the plastic being extruded, of 300° to 600° Fahrenheit. Inside the cylinder is a screw, similar to an auger, which turns, forcing the plastic out through a die. The material is immediately cooled by air and water and is pulled off continuously by means of pullers, of which there are many designs. The basic difficulty in plastic extrusion is the die design and it is in the design of the die and take-off that most of the "hush-hush" and secret rhubarb of the plastic extruder is wrapped up. Plastic extrusion is not positive like metal extrusions and the size of the aperture is usually larger than the finished product, as the speed with which the material is pulled away by the puller is also a determining factor in the size of the finished product. It is necessary, however, to have a separate die for almost every size of pipe which is run, although some small variation in tube size may be run from the same die.

Plastic-extrusion machines vary in output, depending on the size of the cylinder, from a production rate of 50 lb an hour up to more than 1,000 lb per hour. To run a variety of sizes of pipe, it is necessary to have rather a complete range of machines, in order to produce a complete line of pipe and other extrusions. To operate an extrusion plant efficiently, it is necessary to run 24 hours a day, as the heating-up of an extruder and getting a good production run going often take several hours. We operate our plants 24 hours a day and 6 days a week.

In getting into the pipe business, we found that it was not economical to ship pipe very long distances, as the freight rate in ship-

ping pipe is considerably greater than in shipping raw materials and you are also shipping a great deal of air when you ship plastic pipe. With our business expanding over the country, we found that the limit to which we could ship pipe and absorb the freight was about 1,000 miles. Therefore, we are now operating five plants throughout the country at various locations, in an attempt to give the best possible service. It has been our hope that larger stocks in the jobber's hands would go a long way toward effecting this. After all, this is his prime responsibility. To do the jobber full justice, plastic pipe does take up a good deal of space and space costs money. However, plastic pipe is becoming more and more a regular commodity item and jobbers are taking it further into consideration, as far as adequate stocking of the material is concerned.

One of the principal bug-bears of stocking flexible plastic pipe is its poor resistance to ultra-violet rays. It should be protected from sunlight exposure for any long period of time. Polyethylene, which is the basic ingredient of Carlon EF and of other flexible pipes, is particularly susceptible to the effects of the sun's rays. The only known means of combating this is by the addition of carbon black, properly dispersed into the material, so that each particle is shaded. This is not an easy thing to accomplish effectively. You may have noticed that in our advertising we say that Carlon EF pipe is pure polyethylene, processed for further improvement. In our Texas plant all polyethylene which we use is put through a special machine, to accomplish this dispersion. Incidentally, this machine, so far as we know, is unique in the plastics industry. We do add certain other ingredients at this time, but the main reason for doing it is to accomplish carbon-black dispersion as cheaply and as effectively as possible.

To take a mild crack at competition, it is amazing to us to see that several of our competitors are producing pipes that are colored grey, green or bronze. This pipe is perfectly good, so long as it is not subjected to sunlight and of course, in many instances, it is not, but if it is, it is subject to rather rapid deterioration, as ordinary pigmentation accomplishes little more than leaving polyethylene in its natural state. In its natural state the material will show a sharp deterioration in a few weeks' constant exposure to sunlight.

This use of carbon-black dispersion for good sunlight resistance

is a fact that has been established by duPont, Bakelite Corp. and Imperical Chemical Industries of England, which are at this time the only producers of raw polyethylene. Perhaps the most complete studies of carbon-black dispersion were made by Bell Laboratories for the Western Electric Co., which uses polyethylene for wire-cable covering. We think that our carbon-black dispersion is now the best in the business and we hope to improve it, so that our pipe can be exposed to sunlight for a period of years without serious deterioration.

With the advent of plastic pipe came, of course, the necessity for the production of the necessary fittings to go with it. When we started in the pipe busines, we knew that fittings had to be furnished, but we had no conception of the variety and number required. Fittings are made by injection molding, a process very similar to die casting. They can be made in quantity rather inexpensively, after a rather heavy investment in molds has been made. We have about $200,000 invested in molds at this writing and we realize that we shall have to invest a great deal more, before we have a complete line. Service connections, according to most authorities, at the street need metal connectors. Several companies have developed a bronze fitting for this purpose.

The plastic pipe, about which I have been speaking, has mainly been polyethylene pipe, the flexible pipe. This to date has been the pipe that has seen the widest use and probably accounts for as much as 80% of the plastic pipe sold today. It will certainly continue to play a major role in plastic-pipe manufacture. However, pipe manufactured from other materials, such as acetate butyrate, styrene copolymer materials and rigid poly-vinyl chloride, are also used. The latter two materials will play an increasingly important role, because of greater tensile strength and resistance to corrosion from the stronger acids and alkalies. They have applications in chemical and food processing, as well as water- and gas-service lines, and in the oil fields for gathering and lead lines and salt-water disposal. While these materials are of somewhat greater tensile than polyethylene, they must certainly still fall into the category of low-pressure pipes.

A great deal of work, as you may know, is being done with plastic-reinforced Fiberglas. So far, this has not been too successful. In small-sized pipe it is considerably more expensive to manufacture.

The thermo-plastic pipe currently used, of course, can stand reasonably high pressures in small sizes. The two principal techniques employed in the manufacture of reinforced pipes are winding the glass and polyester resin around the mandrel and then curing it by heat. The other method generally used is centrifugally to cast the mass in a rapidly rotating steel tube. One of the difficulties in the latter method is that the heavier glass goes to the outside of the rotating mass, with the result that much of the resin does not get the benefit of reinforcing, and under pressure actual separation between these two zones of material has occurred.

We, at Carlon, are striving in several directions to broaden the range of our piping products. We are spending a lot of money at it from a research standpoint. We have to do so. At the last count we have, in the good old healthy American tradition, about 40 competitors breathing down our necks. Plastics in pipe have two main reasons for being—corrosion resistance and ease of installation. The main stumbling blocks are cost, particularly in the larger sizes of pipe, low tensile, limiting its use to low-pressure applications, and its temperature limitation—one case specifically, its inability to stand hot water. I wouldn't mention these obvious drawbacks of plastic pipe if I didn't think that we were making strides in the right direction. Like the Airplane, Plastic Pipe is here to stay.

EXPERIENCE WITH PLASTIC SERVICE PIPE

BY ALLEN M. SYMONDS*

[*Read September 29, 1953.*]

It is undoubtedly true that water-works men are the most conservative group in the world when it comes to introducing any new material for plant construction. They come rightfully by this conservatism because of the very nature of a water-works system. As we all know, the most costly part of the plant, the distribution system, is buried underground, and this situation naturally results in high cost of labor in proportion to the total cost involved. It is generally considered that the best of material, regardless of cost, is none too good. In adopting material for underground construction, it is the ultimate desire of engineers to use material which will last forever. Just consider, for instance, what it would mean to the city of Boston with its paved streets, cement sidewalks, underground structures and continuous traffic, if it had to replace its system once in, say, every 50 years. Before introducing any new material, we may well take account of stock and see what has been past experience with service-pipe installation.

In my observations of numerous water companies, I find a similarity of material used during different periods in past years. Plants constructed during the late 1800's very frequently used lead pipe for services. Our predecessors undoubtedly believed lead to be the most durable metal available at that time and their judgment appears to be reasonably good.

The original Milford, Mass., water-works plant was constructed in 1882 and the service installations were of lead pipe; 687 of these are still in service. They are now gradually failing and will have to be replaced within the near future. The Grafton, Mass., Water Co. plant, built about 1890, originally had all lead services. In 60 years, these have all been replaced because of failure of the lead pipe.

The next material to meet the approval of our forefathers was

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galvanized iron. Experience has shown that in most waters this pipe tuberculated, became filled up and rusted through within a life-span of about 25 years. In 1920, cement-lined steel and wrought iron pipe, along with brass pipe, became popular for service construction, and there are many original installations of cement-lined pipe in use today. Brass pipe in most waters throughout New England proved unsatisfactory, due to chemical action of zinc, one of the components of brass pipe.

The process of cement-lining steel and wrought-iron pipe has been greatly improved and two water companies on Cape Cod, with which I am affiliated, are now using cement-lined steel pipe as standard construction. Most plants with which I am familiar, however, have been using copper tubing for service-pipe construction since about 1930. To the best of my knowledge, this has proven a very satisfactory material for service-pipe installation. However, we must admit that its use does not date back very far into history and troubles may develop, of which we are not now aware.

History plainly tells us that, with the exception of copper tubing, metal pipe, used for service construction, has its limitations and will not last into eternity as we should like to have it. I have not mentioned cast iron, since its characteristic, structurally, does not permit its use for small service installation. Cast iron, however, has stood the longest test of time and comes the nearest to a forever-lasting material among those now in use for water-works construction.

In presenting what information I can on the use of plastic for service-pipe construction, I am indebted to my former employer, the American Water Works Co., which commenced experimenting with plastic pipe in 1951. At that time, the use of copper and steel was being restricted to those having priority, and on one knew how serious these restrictions might become. Since that time, the subsidiary companies of the American Water Works Co. have installed 2,150 plastic services—149 of which are in New England. They are all constructed of Carlon WS plastic pipe with bronze fittings.

The pipe now being used is a flexible polyethlyene, which is joined to standard copper tubing or iron pipe fittings by the use of bronze adaptors and stainless steel clamps. Original installations were made with a thinner-walled pipe, called Carlon EF and with plastic adaptors.

The adaptors in several instances failed, due to settlement or traffic concussion, and the pipe split at the joint. This situation was remedied by increasing the wall thickness of the pipe by 50% and using bronze adaptors.

The original clamps were stainless steel, but with a screw and clamp body of a different material. This quickly corroded and it became obvious that general failure would result. Although the clamp appears to be still in its experimental stage, the ones now being used are 100% stainless steel and so far have shown no indication of corrosion.

Plastic pipe will not stand hot water, and becomes very soft and pliable at temperatures of 270° F. It also becomes very brittle at 20° F. At the usual water temperatures of 45° to 60° F. it should prove satisfactory as far as flexibility is concerned.

I have with me a recent report of Martin Flentje, chief research engineer for the American Water Works Co., and also individual reports from the managers in New England, who have used Carlon pipe.

A summary of their experiences is as follows:

1. There have been no failures of the plastic pipe of the type now being used.
2. No trouble has been experienced with the bronze adaptors.
3. Difficulty has been experienced with the metal bands, which clamp the pipe to the adaptors, the trouble being in the nature of stripped threads on the screw, or a broken band. Experiments are now being made with a so-called Bandit Tool.
4. Plastic pipe is a non-conductor and therefore can not be thawed by electricity. This has brought objections from prospective users in the colder climates.
5. The pipe has to be carefully laid, as it is subject to crushing or cutting if laid in a rocky trench and carelessly handled. The pipe does not uncoil and stay put like copper, but is springy, and men have to stand on it to hold it down until partially back-filled. All made the comment that the pipe is being used experimentally and its limited period of use does not permit an honest opinion of its value for water-works construction.

In conclusion, I wish to make a few final remarks as to how it looks to me:—

The clamps shown here undoubtedly would be satisfactory for above-ground construction. Offhand they look flimsy for a permanent job underground. The pipe is reported to be inert chemically and not subject to corrosion or pitting. It does appear to be structurally weak, as compared to iron or copper, and in this connection I wish to refer to history and again consider lead pipe.

You who have had occasion to place a pressure gauge on various locations of your system have noticed the constant fluctuation of the needle. This, of course, is due to water surge, caused by varying consumption or action of pumps. On a service line, this surge is quite violent when a faucet is opened or a toilet is flushed. The action of the needle on a pressure gauge might well be compared to a heart beat. This constant throb or pulsation can in time tire out a material such as lead pipe. Invariably lead pipe is expanded where a crack occurs and it finally gets tired and lets go. Plastic pipe has elasticity, which lead or copper does not have, and may be able to cope with this pulsation for years beyond anything yet experienced. If, however, the pipe should change in its characteristic and become brittle, failure might result, as in lead pipe.

I feel that plastic installations have merit and plan to install a few experimentally in plants with which I am associated. If our forefathers or we ourselves had not experimented with lead, galvanized iron, brass, cement-lined and copper tubing, we should not now be aware of their comparative merit.

If a satisfactory clamp can be selected, I suggest that several plastic services be installed experimentally as a calculated risk in the medium- and larger-sized plants. It is recommended that these be installed in outlying districts and where the pressures are 100 lb or less. This will give those following us in the water-works profession an opportunity to profit by our experience.

NEW YORK'S QUEST FOR INTERSTATE WATER

BY KARL R. KENNISON*

[*Read September 30, 1953.*]

New York City's search for an adequate water supply has crossed State borders more than once and in that, as well as other respects, its problem has somewhat resembled Boston's. After the first 100 years of the primitive central-well stage and another 100 years of the primitive bored-log-pipe stage, the first real supply worthy of the name was planned by Colonel DeWitt Clinton, consisting of an aqueduct from the Croton River to a reservoir on Murray Hill, at the present site of the New York Public Library at 42nd Street and 5th Avenue. This was completed in 1842, five years before Boston celebrated its first delivery of water from Lake Cochituate to the Frog Pond on the Common.

Recognition of the need of a substantial increase and a long look into the future by both these large cities came just before the turn of the century, and was furnished by two prominent engineers, well-known honorary members of this Association. In March, 1900, after seven months of intensive study, John R. Freeman showed New York's need of at least 500 mgd and indicated several sources from which it could be obtained, the most economical of which was the Housatonic River, across the State line in Connecticut. Two years previously, Frederic P. Stearns had initiated the water-district idea in recommending that Boston and surrounding communities combine and get their supply by building Wachusett Reservoir on the Nashua River. The fact that this interstate stream flowed for a short distance through Nashua, N. H., was not of sufficient importance at the time to cause any difficulty in making the diversion and the adoption of the Nashua source determined the policy that Boston has since followed, of reaching continually westward for upland supplies. New York, however, concluded not to risk the interstate complications that would certainly

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have resulted from a diversion from the Housatonic River, and finally the Burr-Hering-Freeman report in November, 1903, set up the pattern that has since been followed by New York City: first, the reinforcement of the Croton system by the Catskill system and next, a further extension by the Delaware system.

Altogether there were eight years of intensive preliminary investigation and public education, which finally bore fruit. In 1904 the State constitution was amended to place capital expenditures for water supply outside the municipal debt limit. In 1905 the Board of Water Supply was created as the City's agency for constructing additions to its water supply and the State Water Supply Commission (now the Water Power and Control Commission) was created as a regulatory body.

The first Chief Engineer of the Board of Water Supply, appointed August 1, 1905, was J. Waldo Smith, a past president and honorary member of this Association. He assembled a unique engineering organization that has set a standard for the efficient promotion of public works of great magnitude. He was succeeded June 1, 1922, by Thaddeus Merriman, also an honorary member of this Association, but continued acting as Consulting Engneer. They completed the Catskill system which, as shown on the accompanying map, Fig. 1, brought water from the Schoharie Reservoir via the Shandaken tunnel, and from the Ashokan Reservoir via the Catskill aqueduct to Kensico Reservoir and to Hill View Reservoir, thence distributed via City Tunnel No. 1 under the Bronx, Manhattan and the East River to Brooklyn, and thence by pipe lines to Richmond. The first delivery of Catskill water from Ashokan Reservoir was December 27, 1915, and from Schoharie Reservoir, February 9, 1924. Even before the latter date the Board realized the necessity for immediate studies for an additional supply. Under Mr. Smith's direction, all possible sources within 200 miles were studied. The investigation resulted in a report by Department Engineer Walter E. Spear, also a member of this Association, dated November 9, 1923, as follows.

> "The Delaware River and its tributaries above Port Jervis, together with adjacent streams of the Hudson River basin, all on the westerly and southerly slopes and foothills of the Catskill Mountains, are nearer to the City than any other source of equal capacity and are sufficiently high for gravity delivery to the City. Compared with the supply just considered from the streams

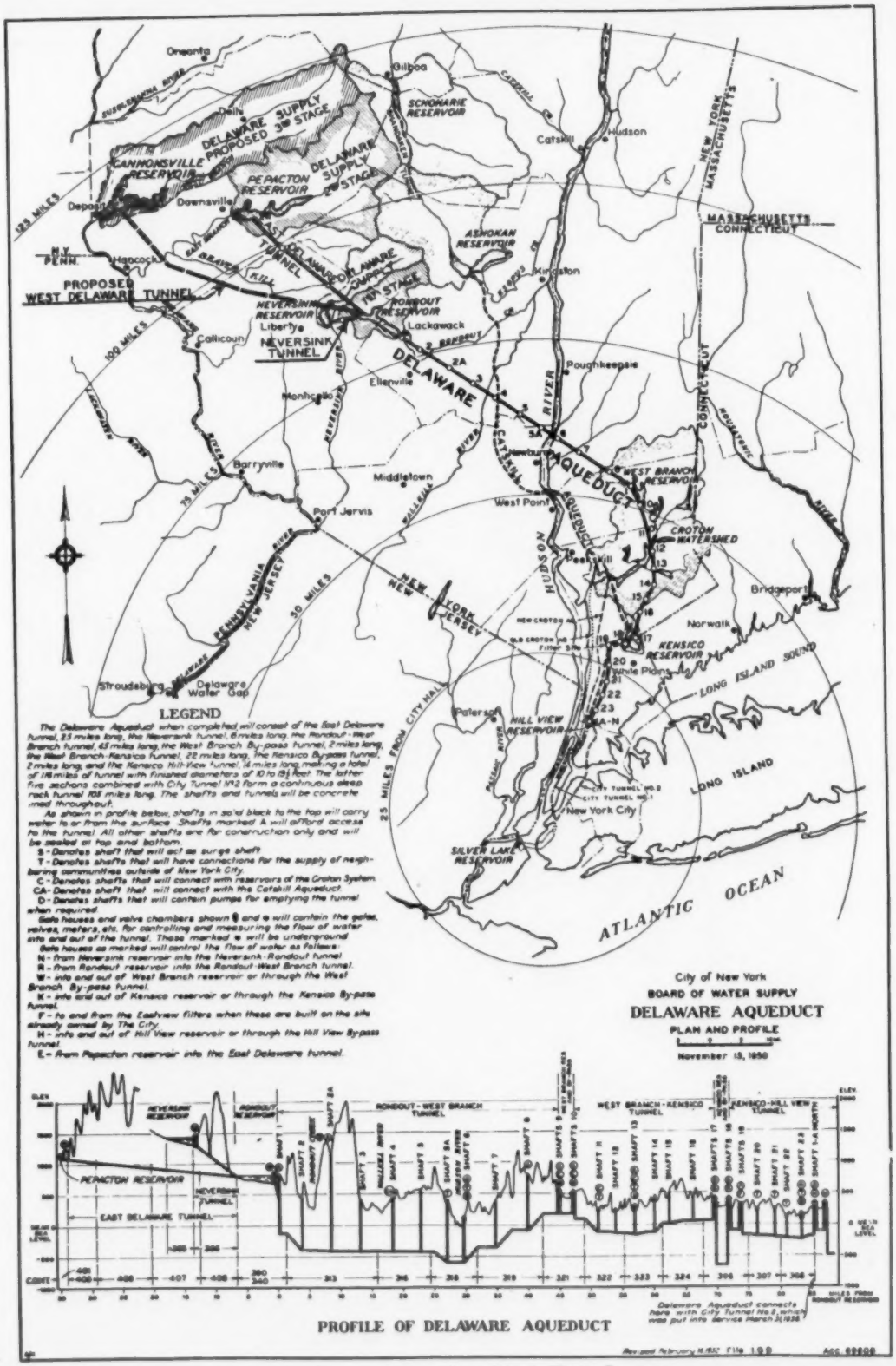

Oneonta
Gilboa
SCHOHARIE RESERVOIR
DELAWARE SUPPLY PROPOSED 3rd STAGE
CANNONSVILLE RESERVOIR
PEPACTON RESERVOIR
DELAWARE SUPPLY 2nd STAGE
Delhi
Deposit
Downsville
Catskill
Hudson
NEW YORK MASSACHUSETTS
MASSACHUSETTS CONNECTICUT
ASHOKAN RESERVOIR
Kingston
DELAWARE AQUEDUCT 1st STAGE
ROUNDOUT RESERVOIR
NEVERSINK RESERVOIR
Liberty
Lackawack
PROPOSED WEST DELAWARE TUNNEL
NEVERSINK TUNNEL
Callicoon
Hancock
N.Y. PENN.
Ellenville
Monticello
Poughkeepsie
DELAWARE RIVER
AQUEDUCT
WEST BRANCH RESERVOIR
Barryville
Middletown
Port Jervis
West Point
CROTON WATERSHED
Peekskill
Bridgeport
Norwalk
KENSICO RESERVOIR
White Plains
LONG ISLAND SOUND
Stroudsburg
Delaware Water Gap
Paterson
HILL VIEW RESERVOIR
New York City
LONG ISLAND
SILVER LAKE RESERVOIR
ATLANTIC OCEAN
LEGEND
The Delaware Aqueduct when completed will consist of the East Delaware tunnel, 25 miles long, the Neversink tunnel, 6 miles long, the Rondout - West Branch tunnel, 45 miles long, the West Branch By-pass tunnel, 2 miles long, the West Branch-Kensico tunnel, 22 miles long, the Kensico By-pass tunnel, 2 miles long, and the Kensico Hill-View tunnel, 4 miles long, making a total of 116 miles of tunnel with finished diameters of 10 to 19½ feet. The latter five sections combined with City Tunnel №2 form a continuous deep rock tunnel 105 miles long. The shafts and tunnels will be concrete lined throughout.
As shown in profile below, shafts in solid black to the top will carry water to or from the surface. Shafts marked A will afford access to the tunnel. All other shafts are for construction only and will be sealed at top and bottom.
S - Denotes shaft that will act as surge shaft.
T - Denotes shafts that will have connections for the supply of neighboring communities outside of New York City.
C - Denotes shafts that will connect with reservoirs of the Croton System.
CA - Denotes shaft that will connect with the Catskill Aqueduct.
D - Denotes shafts that will contain pumps for emptying the tunnel when required.
Gate houses and valve chambers shown ■ and ● will contain the gates, valves, meters, etc. for controlling and measuring the flow of water into and out of the tunnel. Those marked ● will be underground.
Gate houses as marked will control the flow of water as follows:
N - from Neversink reservoir into the Neversink - Rondout tunnel.
R - from Rondout reservoir into the Rondout - West Branch tunnel.
W - into and out of West Branch reservoir or through the West Branch By-pass tunnel.
K - into and out of Kensico reservoir or through the Kensico By-pass tunnel.
F - to and from the Eastview filters when these are built on the site already owned by The City.
H - into and out of Hill View reservoir or through the Hill View By-pass tunnel.
E - from Pepacton reservoir into the East Delaware tunnel.
City of New York
BOARD OF WATER SUPPLY
DELAWARE AQUEDUCT
PLAN AND PROFILE
November 15, 1950
PROFILE OF DELAWARE AQUEDUCT
Delaware Aqueduct connects here with City Tunnel No 3, which was put into service March 31 1936

FIG. 1.—GENERAL PLAN OF NEW YORK'S WATER SUPPLY.

wholly within the Hudson River basin, it will be shown that a supply from these sources would be cheaper, softer and in the end much larger, so that, aside from the difficulties and delays that may be encountered in acquiring interstate waters, these Delaware River sources afford the best opportunity for developing a large and satisfactory supply of water for New York City."

Finally, the Board submitted its plan for the Delaware supply to be developed in three stages, for a total of 600 mgd (200 less than the 800 mgd now being sought). After five months' consideration, it was approved by the Board of Estimate in January, 1928, and submitted for approval to the State Water Power and Control Commission. Approval was given May 25, 1929, but not until after the State of New Jersey, on May 13, started action in the U. S. Supreme Court to prevent New York from diverting any water from the Delaware.

The First Delaware River Case

This case was practically coincident with, as well as very similar to, the Massachusetts-Connecticut case. The Special Master in the Connecticut case, Charles W. Bunn, Esq., was appointed December 2, 1929, and submitted his report May 19, 1930. The Special Master in this first Delaware case, Charles N. Burch, Esq., was appointed January 27, 1930, and submitted his report February 2, 1931. The opinion of the Court was delivered in the Connecticut case by Mr. Justice Butler on February 24, 1931, and in the Delaware case by Mr. Justice Holmes on May 4, 1931. Both decrees, which followed shortly afterward, authorized the diversion of the interstate water. Boston was allowed the full amount sought, but New York's allotment was reduced from the 600 mgd applied for to 440 mgd.

The conduct and outcome of these cases is a well-known matter of record, particularly to members of this Association. Frank E. Winsor, a past president and honorary member of the Association, was Chief Engineer of the Metropolitan District Water Supply Commission at the time, and Thaddeus Merriman had succeeded Mr. Smith as Chief Engineer of the New York Board of Water Supply, as above stated. The September, 1931, issue of the Association's Journal published papers by each of these distinguished engineers which, together with their discussions, covered the entire field in masterly fashion. The opinion of the Court in the Connecticut case concluded briefly as follows:

"Drinking and other domestic purposes are the highest uses of water. An ample supply of wholesome water is essential. Massachusetts, after elaborate research, decided to take the waters of the Ware and Swift rather than to rely on the sources in the eastern part of the Commonwealth where all are, or are liable to become, polluted. We need not advert to other considerations, disclosed by the evidence and findings, to show that the proposed use of the waters of the Ware and Swift should not be enjoined."

In the Delaware case, Mr. Merriman's paper brought out clearly the various principles applicable to water diversion: the riparian doctrine and its modifications as practiced in the Western states, the doctrine of appropriation, interstate compacts as recently promulgated, and the doctrine of equitable apportionment. In delivering the opinion of the Court, Mr. Justice Holmes stated:

"We are met at the outset by the question what rule is to be applied. It is established that a more liberal answer may be given than in a controversy between neighbors members of a single State. Connecticut v. Massachusetts, February 24, 1931. Different considerations come in when we are dealing with independent sovereigns having to regard the welfare of the whole population and when the alternative to settlement is war. In a less degree, perhaps, the same is true of the quasi-sovereignties bound together in the Union. A river is more than an amenity, it is a treasure. It offers a necessity of life that must be rationed among those who have power over it. New York has the physical power to cut off all the water within its jurisdiction. But clearly the exercise of such a power to the destruction of the interest of lower States could not be tolerated. And on the other hand equally little could New Jersey be permitted to require New York to give up its power altogether in order that the river might come down to it undiminished. Both States have real and substantial interests in the River that must be reconciled as best they may be. The different traditions and practices in different parts of the country may lead to varying results but the effort always is to secure an equitable apportionment without quibbling over formulas."

Following the unavoidable delay caused by the court case, and as soon as the decree favorable to New York was handed down, work was started on the construction of the first stage of the Delaware supply. This Delaware System is delineated in plan and profile on Fig. 1, which shows the location of the reservoirs and tunnels and their relation to the earlier Catskill and Croton Systems.

The Delaware Supply—Three Stages

The first stage includes Neversink Reservoir, with a capacity of 35 billion gallons, impounding the run-off from 93 sq mi drainage area

of the Neversink River, which is tributary to the Delaware River just below Port Jervis. The main dam is a rolled-fill earth dam, 195 ft high, 2,820 ft long, with a flow line at elevation 1,440 ft above mean sea-level. From this reservoir a tunnel, 10 ft in diameter and 5.5 miles long, diverts the water through the divide into the City's Rondout Reservoir. Dissipation of energy due to the difference of 600 ft in the reservoir flow-line elevations was necessary at the tunnel outlet. To accomplish this a power plant was constructed, and will be operated, by the Central Hudson Gas & Electric Corp. under a 50-year agreement, which will compensate the power company for certain diversion damages.

The first stage also includes the Rondout Reservoir, created by the Merriman Dam, a rolled-fill dam, 195 ft high and 2,400 ft long, with flow line at elevation 840. It impounds about 49 billion gallons from 95 sq mi drainage area of Rondout Creek, a tributary of the Hudson River. Rondout Reservoir will serve as a receiving basin for the planned diversions from the Delaware basin. The water is brought to New York City through the Delaware Aqueduct, a deep tunnel of the unprecedented length of 85 miles, roughly paralleling the older Catskill Aqueduct. This tunnel required 32 construction shafts at 26 locations, three of these, including No. 6 at the Hudson River crossing, being equipped as emergency unwatering shafts. The West Branch Reservoir, which was originally constructed as tributary storage in the Croton System in 1895, is utilized as an equalizing basin on the Delaware Aqueduct, water entering at the northerly end from uptake Shaft 9 and leaving the reservoir at the southerly end through downtake Shaft 10. A by-pass tunnel connecting those shafts permits direct delivery from Rondout to Kensico, if desired.

In normal operation, the Delaware Supply is delivered into Kensico from uptake Shaft 17, located on the easterly side of that reservoir. Here the water is mixed with Catskill water and receives further natural purification from storage. Leaving Kensico at downtake Shaft 18, the tunnel continues westerly to uptake and downtake Shafts 19, where an area is provided for filter beds if required in the future, and then southerly to Hillview reservoir. A by-pass tunnel under Kensico reservoir between downtake Shaft 17 and uptake Shaft 18 permits the elimination of that reservoir and delivery directly to

Hillview if necessary. Water from Kensico is delivered into Hillview reservoir through both the Catskill and Delaware aqueducts and thence to City Tunnels Nos. 1 and 2, Hillview being the last equalizing reservoir before reaching the centers of consumption.

This entire first stage of the Delaware Supply, as above described, is now completed, except for miscellaneous details of buildings and operating works at the various control chambers. As far back as April 5, 1944, a run-of-the-stream diversion of the Rondout Creek was obtained by means of a temporary connection in Shaft 1 of the Delaware aqueduct. Storage in the Rondout Reservoir was first drawn upon in June, 1951. Although, as above stated, the reservoir will hold 49 billion gallons, it was not allowed to fill last spring on account of certain items of construction work yet to be completed. Impounding in the Neversink Reservoir was started June 1, 1953.

The construction of the second stage of the Delaware supply is well advanced and will be completed in about two years. It should be ready for storage in another year. This second stage consists of Pepacton Reservoir on the East Branch of the Delaware River and the East Delaware Tunnel, which diverts the water to Rondout Reservoir. The reservoir is created by the Downsville Dam, a rolled-fill earth structure, 204 ft high and about 2,450 ft long, with flow line at elevation 1,280. This reservoir has an available capacity of 143.5 billion gallons and will impound the runoff from 372 sq mi drainage area of the East Branch of the Delaware River. The East Delaware Tunnel to Rondout Reservoir is 11′-4″ in diameter and 25 miles long. Dissipation of energy, due to the difference of 440 ft in the reservoir flow-line elevations, will be accomplished by a power plant similar to that described above at the outlet of the Neversink Tunnel and built and operated under a similar compensating agreement with the Rockland Light & Power Co.

The third stage of the Delaware project is materially different from that originally proposed. The inadequacy of the limitation of 440 mgd, imposed by the Court's decree of May 25, 1931, to meet the growing demand by the City was so apparent that on January 6, 1948, the Board established the New Sources Division with a Board of Consulting Engineers, headed by the late Roger W. Armstrong, a former Chief Engineer of the Board of Water Supply and a member of this

Association. The entire field of possible new sources was thoroughly studied and a recommendation adopted, enlarging the third stage of the Delaware project by substituting a single development on the West Branch of the Delaware for several smaller developments on other tributaries. As now proposed, the third stage of the Delaware supply consists of a reservoir, created by a dam located about 4 miles downstream from the hamlet of Cannonsville, and a tunnel about 45 miles long to Rondout Reservoir. The Cannonsville Reservoir will have an available capacity of about 91 billion gallons and will impound the runoff from 450 sq mi drainage area of the West Branch of the Delaware River. The proposed flow line is at elevation 1,150. The application now before the Supreme Court of the United States seeks the right to increase the diversion from the Delaware from 440 mgd to 800 mgd.

The water-supply situation in the latter half of 1949 was so acute that emergency measures appeared necessary. Accordingly, a temporary pumping plant was built near Chelsea, Dutchess County, N. Y. The plant is equipped to chlorinate heavily and deliver 100 mgd of Hudson River water into the Delaware aqueduct through the 48-inch diameter riser pipe, which was a part of the original construction of Shaft 6. This project received prompt approval by the New York State Water Power and Control Commission and was built in record time. To date, the pumps have been operated only for test and maintenance. The Commission, in granting its approval stated:

> "Such use shall be permitted only during the present water supply emergency of the City for the period prior to the final completion of the present construction work in connection with the development by the City of the Delaware River and its tributaries and the availability of such water for use in the City, and in no event beyond January 1, 1957, at which time the plant must be completely abandoned and the equipment in it removed, unless upon further application by the City to this Commission, it can be shown that emergency conditions do exist and the Commission will extend this date."

To supplement the plan and profile on Fig. 1, the operation of the entire system is shown diagrammatically by Fig. 2, which traces the actual distribution for the year 1952 from the sources to the points of delivery.

The accompanying chart, Fig. 3, shows graphically the development of New York's sources over the years, and how these stages in the development of the Delaware supply are required to meet expected

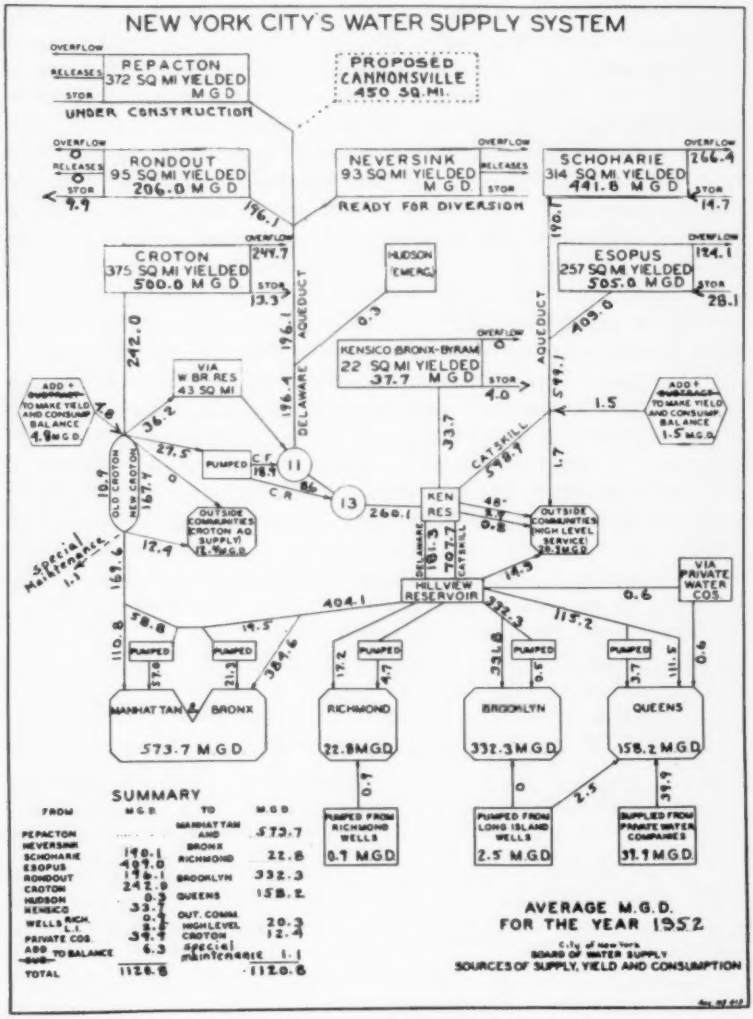


FIG. 2.—SUPPLY AND DISTRIBUTION—1952.

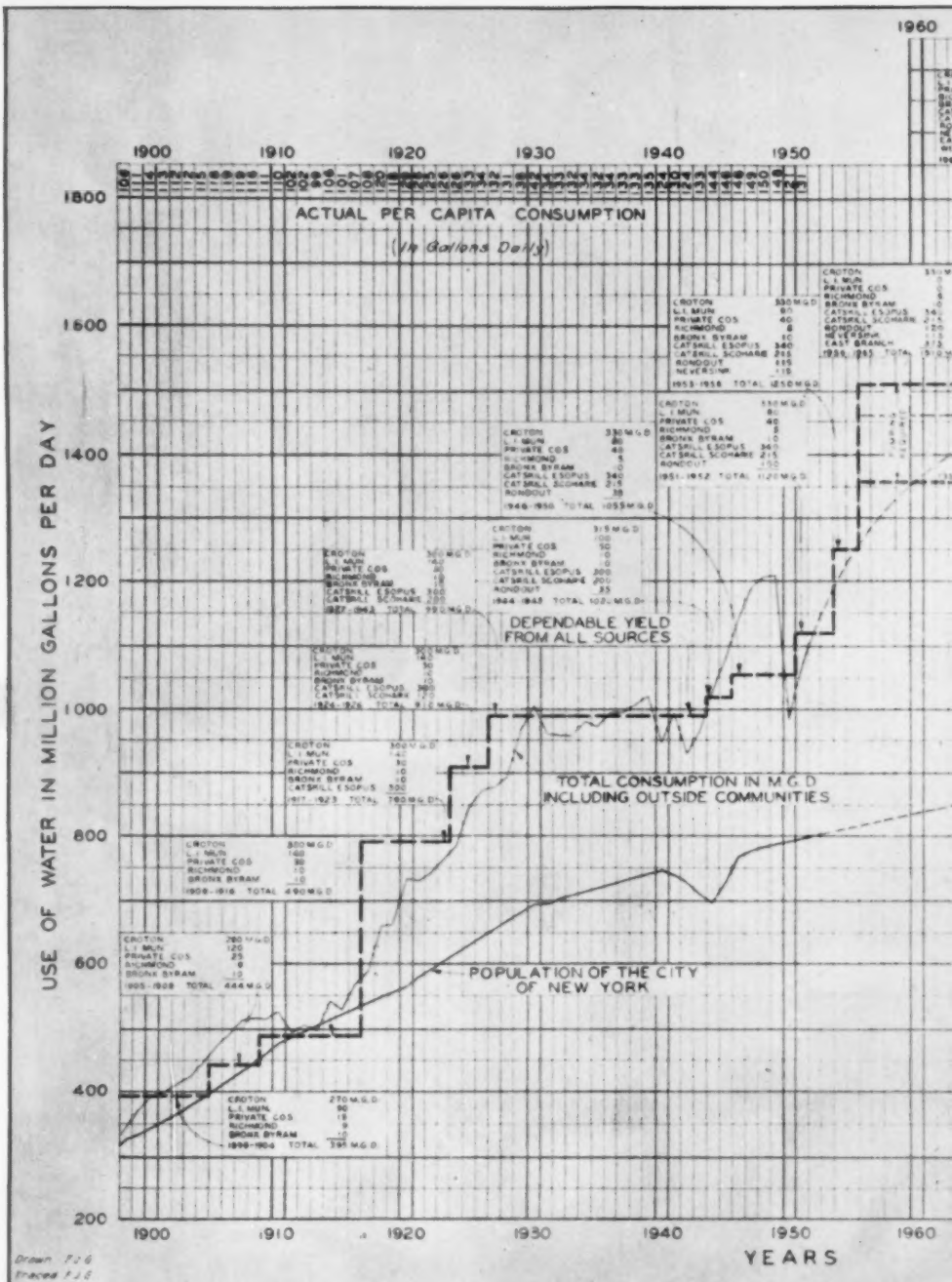
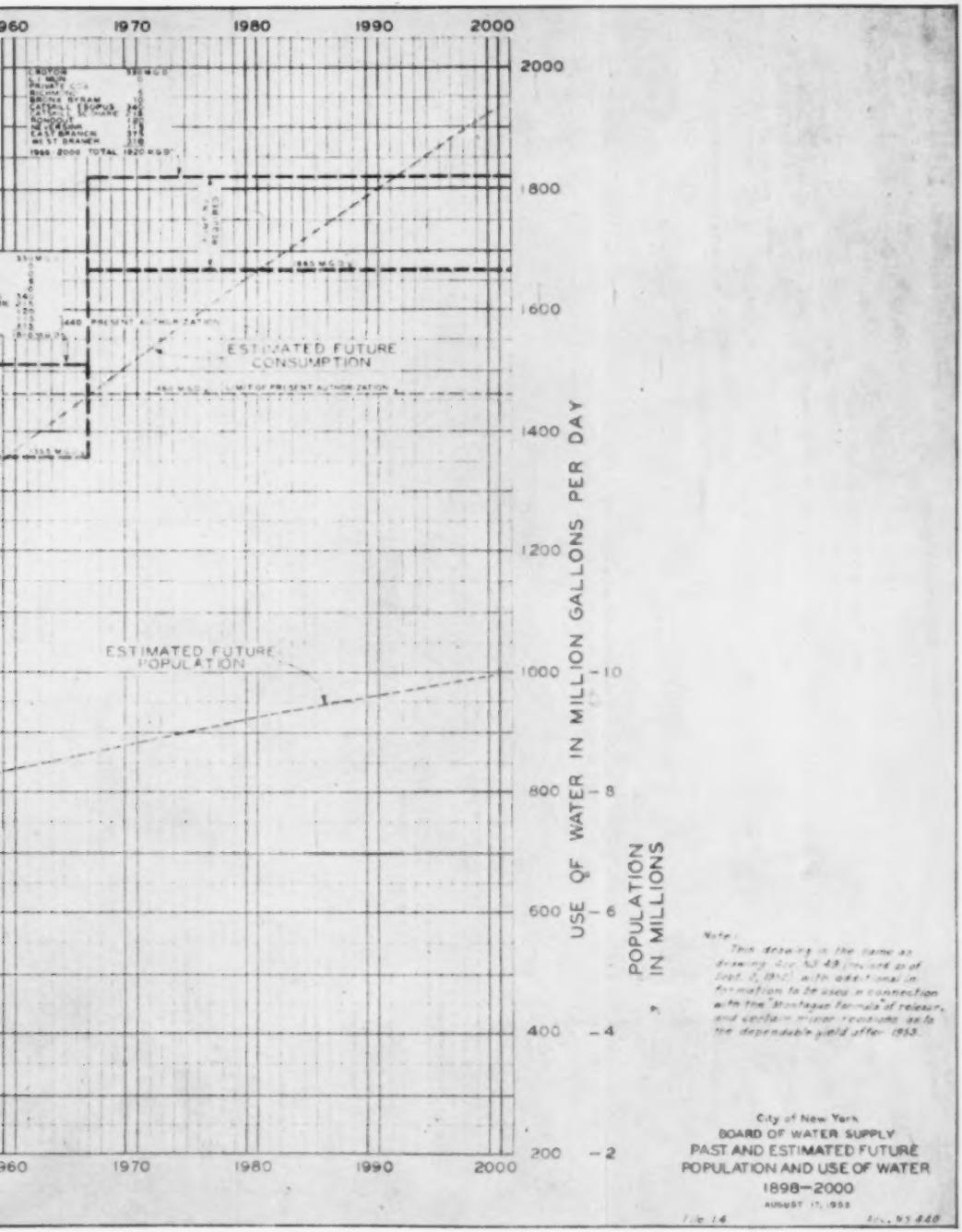


FIG. 3.—ACTUAL AND ESTIMATE



IMATED CONSUMPTION AND SAFE YIELD.

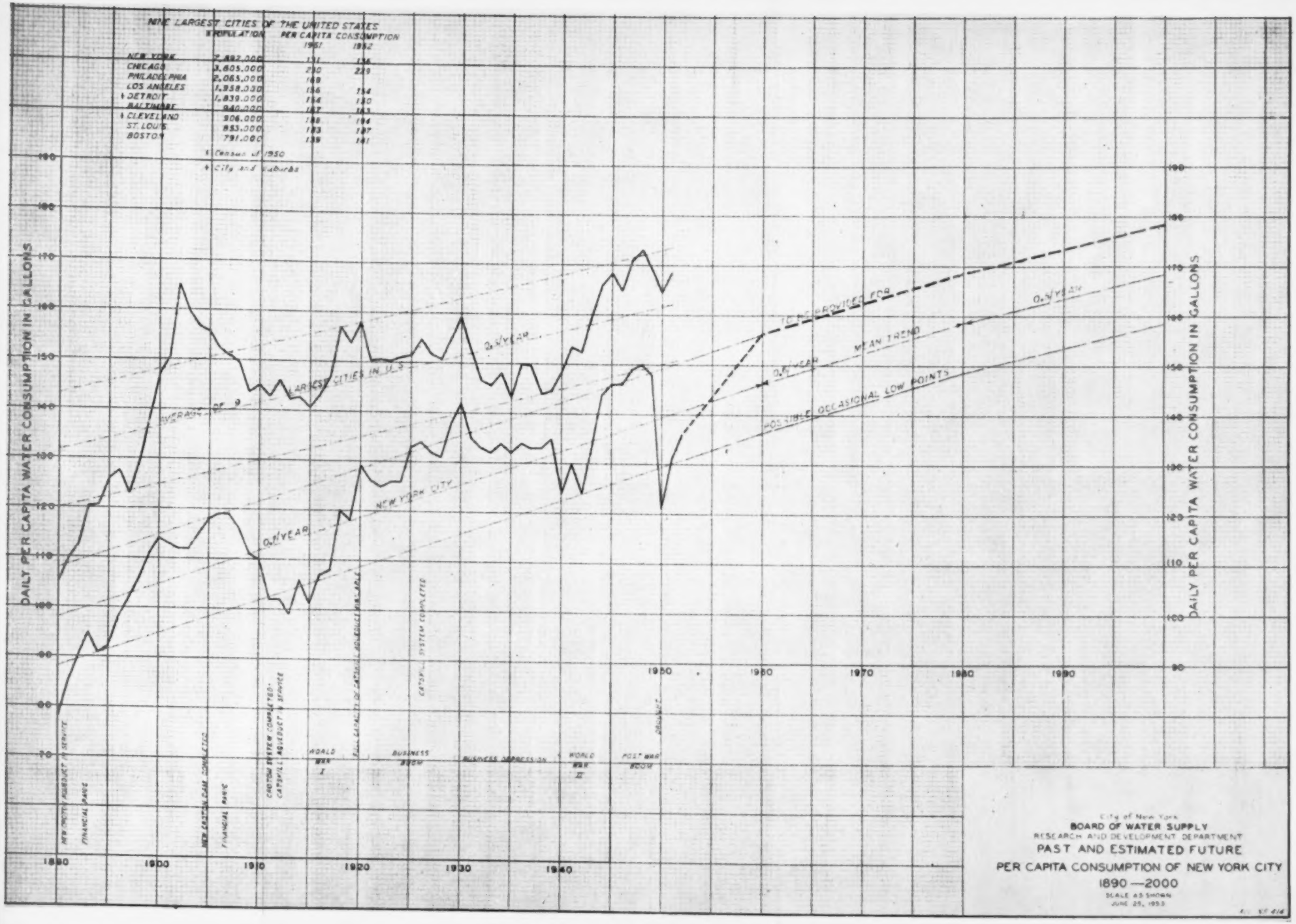


FIG. 4.—CONSUMPTION PER CAPITA IN NINE LARGEST CITIES.

needs and to provide a reserve. At best such a reserve can hardly be called adequate. The development of these sources is also shown in concise tabular form as follows:

Source	Continuous safe yield in mgd available in 1905-9	1917	1924-7	1944-6	1951	1954	1956	1967
Long Island								
Municipal	140	140	140	80	80	80	0	0
Private Companies	30	30	30	40	40	40	0	0
Croton	300	300	300	330	330	330	330	330
Richmond	10	10	10	5	5	5	5	5
Bronx-Byram	10	10	10	10	10	10	10	10
Via Catskill Aqueduct								
Ashokan Reservoir		300	300	340	340	340	340	340
Schoharie Reservoir			200	215	215	215	215	215
Via Delaware Aqueduct								
Rondout Reservoir				35	100	115	120	120
Neversink Reservoir						105	105	105
Additional by new petition						10	10	10
Pepacton Reservoir							335	335
Additional by new petition							40	40
Cannonsville Reservoir by new petition								310
	490	790	990	1,055	1,120	1,250	1,510	1,820

New York's Consumption Needs

Figure 3 gives a comprehensive picture of the growth of New York's water-supply needs. There are two interesting points to note in a comparison of this situation with that in Boston: (1) New York's problem cannot, on account of its magnitude alone, be matched anywhere else, the current rate of consumption being about 6 times that of the entire Boston Metropolitan District with its 23 cities and towns. (2) New York has almost from the beginning been in a nip-and-tuck race to develop new sources to meet its needs and has never had a comfortable, or even a reasonably adequate, reserve. In contrast, the last major addition to the Boston supply multiplied the safe yield by about 2¾.

The tense situation which has recently existed in New York is well illustrated in the chart. Interstate litigation, the depression of the 1930s and World War II so delayed the City's construction program that the safe yield of its sources was less than the consumption in each of the last seven years, except in 1950 and 1951, when the consumption was temporarily reduced by a drastic conservation campaign, necessitated by the critical water shortages in 1949 and 1950.

In a city like New York the question of metering and waste prevention is a very live one and is largely a matter of economics. Much is being done by the City's operating Department of Water Supply, Gas and Electricity to detect and correct wastes, and increasing appropriations for that purpose are sought annually. Contrary to some widely circulated opinions, New York is not an extravagant user of water, as shown by the following statistics for the year 1952 for nine of the largest cities of the United States. The total supply for all purposes, expressed in gallons per capita per day, is as follows:

Chicago	229
Cleveland (incl. suburbs)	194
St. Louis	187
Philadelphia	165
Baltimore	163
Los Angeles	154
Detroit (incl. suburbs)	150
Boston	141
New York	136

The writer has had many occasions in the past to make estimates of water consumption and the effect of metering and is forced to the conclusion that the effect in reducing the consumption is largely temporary. Undoubtedly there is some degree of permanency, and this is reflected in the statistical information and estimate for the future shown in the accompanying chart, Fig. 4. This shows a general overall trend which points to an annual increase of 0.5 gpcd in spite of ups and downs (plus or minus 7%), which vary with business conditions and the extent of which cannot be predicted with any certainty. On that account, in making plans for major water-supply works, the planning and construction of which may require at least 15 years, we must consider the upper limit of this band which represents the uncertain variation in the rate of consumption. Our estimates compare

favorably with those recently shown in other published reports as follows:

FUTURE CONSUMPTION IN GALLONS PER CAPITA PER DAY AS ESTIMATED BY VARIOUS AGENCIES

	Engineering Panel on Water Supply (Mayor's committee) 1950	Incodel report of Pirnie, Albright & Friel 1950	New York Dept. of Water Supply, Gas and Electricity 1951	New York Board of Water Supply 1952
1960	155	160	152	157
1970	162	(163)	160	163
1980	168	167	165	169
1990	172	(171)	168	174
2000	177	175	170	179

As indicated on the chart, the past record of New York City's ups and downs in per-capita consumption shows that the upward trend has been at a somewhat higher rate—namely, about 0.7 gpcd per year—and that the ups and downs are within a band with a width of as much as 20 gpcd, or plus or minus 10 gpcd.

In projecting this into the future it has been assumed that this trend will decrease after 1960 to 0.6, and after 1980 to the same general trend as indicated by the average of all the nine large cities—namely, 0.5 gpcd per year.

ESTIMATED POPULATION AND CONSUMPTION

	Population of New York City	Approx. gal per capita per day Average of ups and downs	Quantity that must be provided	Consumption by New York City (mgd)	Supplied to outside communities (mgd)	Total consumption (mgd)
1950 (Actual)	7,892,000	121		950	29	979
1960	8,366,000	147	157	1313	50	1363
1970	8,785,000	153	163	1432	80	1512
1980	9,210,000	159	169	1556	105	1661
1990	9,598,000	164	174	1670	125	1795
2000	9,955,000	169	179	1782	145	1927

The Incodel Plan

No discussion of the current problems involved in New York City's water supply would be complete without a reference to a comprehensive plan of developing the water resources of the entire Delaware River Basin which has been proposed by the Interstate Commission on the Delaware River Basin, referred to as "Incodel". In the development of this plan the Commission retained Malcolm Pirnie, a member of this Association, of New York, and Albright & Friel of Philadelphia, whose report was published in August, 1950. Their recommendation involved a Tri-State compact between New York, New Jersey and Pennsylvania. The plan was designed to take care of water-supply needs distributed as follows:

For New York City, in addition to the 440 mgd from diversion works already under construction on the Neversink River and the East Branch of the Delaware River, as permitted by the Supreme Court Decree of 1931	510 mgd
Northern New Jersey Metropolitan District	420 mgd
Southern New Jersey Metropolitan District	100 mgd
Philadelphia	500 mgd
Philadelphia Suburban Water Co.	100 mgd
Region between Easton and Philadelphia	50 mgd
Wilmington, Del., area	50 mgd
	1,730 mgd

This was to be developed in two stages. The plan also provided for a considerable increase in the low flow to be maintained in the river. The ultimate goal set for the vicinity of Trenton, N. J., was 4,800 cfs, of which 4,000 cfs was the aim of the first stage of the development. The principal features of the plan are shown on a map, Fig. 5.

The first stage of the proposed Incodel development included the Cannonsville Reservoir for river regulation and the Barryville Reservoir, the function of which was to make possible diversion at high-flow stages through a high-capacity tunnel to a storage reservoir on the Neversink River at Godeffroy. The Cannonsville Reservoir was identical with that now proposed by the City, except that the flow line was fixed 13 ft higher at elevation 1,163 and except that no delivery tunnel was necessary, as is the case with the City's development.

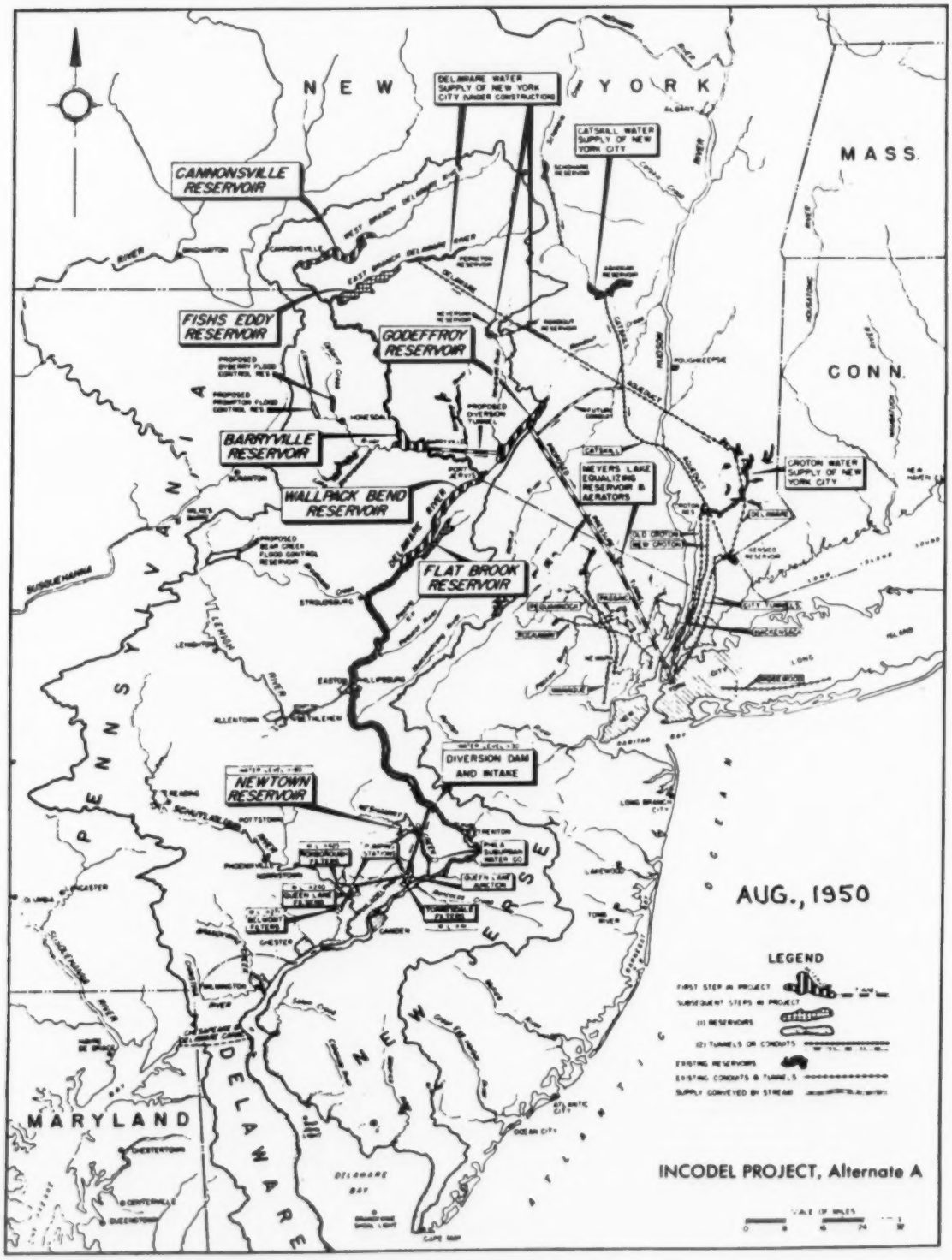


FIG. 5.—TRI-STATE PLAN OF INCODEL.

Godeffroy Reservoir, which would have the very large storage capacity of 278 billion gallons, would be used to deliver water to New Jersey and New York through a pressure tunnel and to maintain certain minimum dry-weather flows in the lower river. The tunnel, which would cross the northeasterly corner of New Jersey and terminate in Brooklyn, would be of varying diameter, would have an equalizing reservoir en route, known as Meyer's Lake Reservoir, and could be tapped at any convenient shaft head. Wallpack Bend Reservoir would also be constructed under Stage 1 in connection with the delivery of water to Pennsylvania. This would be accomplished either by gravity through a tunnel or by pumping plant located on the main river at Yardley, a few miles above Trenton.

The second stage would add Fish's Eddy Reservoir on the East Branch and Flat Brook Reservoir on a tributary in New Jersey, and certain other regulating reservoirs, tunnels and pumping plants located in the vicinity of Philadelphia.

In view of all the circumstances, it certainly is a fair assumption that Incodel, in spite of its many advantages, cannot now be considered a live issue. This is particularly true in view of the fact that Governor Fine of Pennsylvania on June 7, 1951, appointed a Water Resources Committee to appraise the Incodel plan. This Committee reported on February 7, 1952, rejecting the plan and stating that the future water-supply needs of the Greater Philadelphia area could better be accommodated by the construction of reservoirs on tributaries of the Delaware River within Pennsylvania's own borders.

Furthermore, to put Incodel into effect required certain favorable action by all the three state legislatures. Although enabling acts were passed by New York and New Jersey, Pennsylvania failed to pass the necessary legislation and New York City could not further delay the extension of its sources. Accordingly, it made application on January 30, 1950, to the New York State Water Power and Control Commission for permission to construct the Cannonsville Reservoir on the West Branch of the Delaware. After lengthy hearings in the spring and summer of that year, the application was approved November 14, 1950.

The Commission's approval was, of course, subject to the approval of the United States Supreme Court. Its decree of 1931 limited

the diversion to 440 mgd, but provided that any of the parties involved could reopen the case and apply for a modification. That provision enabled New York to file its petition, requesting authorization of an additional 360, making a total of 800 mgd.

The Current Delaware River Case

The petition of April 1, 1952, by the City did not initiate a new case before the Supreme Court, but merely reopened the first case under a provision of the decree which stated:

> "Any of the parties hereto, complainant, defendants or intervenor, may apply at the foot of this decree for other or further action or relief and this Court retains jurisdiction of the suit for the purpose of any order or direction or modification of this decree, or any supplemental decree that it may deem at any time to be proper in relation to the subject matter in controversy."

New York State filed its support of the City's petition on April 23. Pennsylvania and New Jersey opposed New York's petition in answers which were promptly filed May 16 and June 2, respectively. The Citizens Budget Commission of New York City also on May 26 asked leave to appear as *amicus curiae,* but this request was denied by the Court on June 2.

On June 9, Kurt F. Pantzer, Esq., of Indianapolis, Ind., was appointed Special Master to take evidence and report his recommendations.

The city of Philadelphia on December 15 moved to intervene and file an answer of its own. This was opposed by all three States in argument before the Court itself on March 9, 1953, and that city's intervention was denied in a finding handed down April 6.

To determine when releases should be made, the original decree established two gaging points, to indicate when the natural flow drops below 0.5 cfs per sq mi, and the releases required were directed to maintaining that specified rate of flow at Port Jervis, N. Y., where the Delaware leaves New York State, and also at Trenton, N. J., the head of tidewater. The actual rate of release, however, was limited to a maximum of 0.66 cfs per sq mi of the area tributary to each point of diversion.

The City's petition of April 1, 1952, in addition to requesting an increase in the amount of diversion from 440 to 800 mgd, requested

that a new method of release be substituted, abandoning the two downstream gaging stations as criteria in favor of stations to measure the natural flow at the diversion points themselves. The request was for a release formula of the type which had been proposed by Incodel, or specifically: that the rate of release at each diversion point be 50% of the mean annual runoff, as determined by observations covering the 13-year period 1928 to 1941, whenever the recorded rate of flow falls below that which is exceeded 90% of the time; and that the rate of release be 25% of the mean annual runoff, whenever the rate of flow is between that which is exceeded 90% and that which is exceeded 76% of the time; and that no release be required when the rate of flow is greater than that which is exceeded 76% of the time. Note that in any event the State Department of Conservation requires certain releases, in order to insure that the flow below the diversion dams does not drop below a specified minimum.

In addition to the testimony in support of its petition, the City has filed an amended petition and has submitted supplementary testimony, involving an entirely new release formula, to take effect upon the completion of the already authorized second stage of the Delaware supply. This is the formula referred to in the press release of June 22, 1953, quoted in the conclusion of this paper.

From a practical standpoint, operation under this new formula would be greatly simplified, due to the reduction of a number of control points to only one—namely, the existing gaging station of the United States Geological Survey at Montague, N. J. This station is located about 8½ miles below Port Jervis and records the effect of all the City's developments upon the flow in the main river, a feature which makes it preferable to the Port Jervis gage, which is located upstream from the mouth of the Neversink and hence does not record the flows from that tributary. If this new Montague formula were accepted, the City would maintain, within practicable limits, a flow in the Delaware River at Montague equal to 1,750 cfs, or approximately 0.503 csm, except that at first, until the third stage with Cannonsville Reservoir is completed, the rate to be maintained would be only 1,525 cfs, or approximately 0.438 csm.

Furthermore, this new formula sets up a working relation between the actual rate of consumption and the safe yield in a period

of drought. The fact that the supply is to be increased in major steps is well illustrated in Fig. 3. The consumption, on the other hand, increases more or less gradually, although at times erratically. As a result, there is always a surplus supply after each new development is placed in operation until the rate of consumption catches up. The over-flow, or so-called waste, over reservoir spillways is always evident, except in periods of drought, and furthermore is always necessarily excessive for a period of years after each new reservoir is added to any supply. The Montague formula would insure that as much of this excess flow as New York could safely permit would be released during the dry months of the year, when most needed in the lower river, rather than held back to be wasted in the following spring months without any material benefit to the river.

This feature of the Montague formula would be accomplished by a provision that the City would annually estimate the consumption from all its sources during the next calendar year, not exceeding by more than 20 mgd that in any previous calendar year, and on this basis determine the anticipated excess over and above the safe yield of all its sources available without pumping, namely 1,355 mgd before the completion of the third stage, corresponding to an authorized diversion limited to 490 mgd, and 1,665 mgd after the completion. Eighty-three per cent of this annually estimated excess, but not more than 70 billion gallons, would be released from storage, to increase the above-stated minimum rate of flow to be maintained in the river at Montague during the dry months of the year, commencing June 15 and continuing until October 15, or as much longer as such excess for release held out, with a limit of March 15 of the following year. This increase in the minimum rate of flow is determined by the provisions of the formula so that the additional benefit would, even in a very dry year, be spread over at least 120 days.

Since the case is still pending before the Special Master and the Court, it is not appropriate to discuss further this Montague formula. The above is merely a statement of the facts as to its principal provisions. There are other features of the testimony which New York has introduced and these also, for the same reason, will not be discussed. It will be sufficient at this time merely to list briefly the principal witnesses that have testified:

For New York City:

Irving V. A. Huie, President of the Board of Water Supply
Henry Z. Pratt, Jr., Deputy Chief Engineer and head of the Research and Development Department
Vincent G. Terenzio, Division Engineer in that Department
Joseph B. Glancy, Biological Engineer
Frank A. Marston, Consulting Engineer, a member of this Association
Bostwick H. Ketchum, Scientist in Charge, Woods Hole Oceanographic Institution
and the writer

For State of New Jersey:

Howard T. Critchlow, Chief Engineer and Director of the Division of Water Policy and Supply of the New Jersey Department of Conservation and Economic Development
Arthur L. Sherman, Consulting Engineer
Thomas S. Cassedy, Consulting Engineer
Ezra D. Whitman, Consulting Engineer, a member of this Association
Sheppard T. Powell, Consulting Engineer
Howard W. Acken, Supervising Engineer of the Delaware and Raritan Canal
Herbert H. Smith of the New Jersey Department of Conservation and Economic Development
Henry W. Peterson, Secretary of the South Jersey Port Commission
Leigh W. Merrill, District Chief Public Health Engineer of the New Jersey Department of Health
Thurlow C. Nelson, Professor of Biology, Rutgers University
Harold H. Haskin, Professor of Zoölogy, Rutgers University

For the Commonwealth of Pennsylvania:

J. Harry LaBrum, President, Chamber of Commerce, Greater Philadelphia
Samuel S. Baxter, Water Commissioner, Philadelphia
Samuel A. Greeley, Consulting Engineer
Charles E. Ryder, Consulting Engineer

William Howard Corddry, Consulting Engineer
Theodore R. Haseltine, Consulting Engineer
Abel Wolman, Consulting Engineer

The case involves many features which will be very interesting to the water-supply profession when the completion of the case makes it possible to discuss them. Formal hearings are scheduled to commence October 15.

The Hudson River Source

Suggestions that have been made, that the New York Board of Water Supply abandon its proposed extension to the West Branch of the Delaware River and instead develop an additional supply pumped from the Hudson River, have a familiar ring, because the Boston Metropolitan District has faced the same problem. It has always been possible to pump a supply of ample quantity from the Merrimack River, only 25 miles from the State House in the heart of the District, but the Commission, the Department of Public Health, and the Legislature, reflecting public opinion in Massachusetts, decided in favor of upland sources, relatively free from pollution, even though it might be somewhat cheaper to pump and filter and otherwise treat the river water, polluted by sewage and industrial wastes.

It is fair to assume that the previous recommendation of the Special Master, the opinion and decree of the Supreme Court, the rulings of the State Water Power and Control Commission, and the recent findings of the Mayor and his Advisory Board have eliminated the Hudson River as a source comparable in desirability with the proposed available upland supply, but it still remains as a potential source and is receiving and will receive the full consideration of our Research and Development Department.

The Hudson River has a close relation to the City's water-supply problem in a section of the public mind and is a matter of considerable interest to this Association. On that account, the reasons for its recommended rejection deserve to be recounted in detail.

The Hudson River had recent prominence as a possible source of water supply for New York City through a proposal made by Lawrence T. Beck, Consulting Engineer, and recommended to the Board of Water Supply February 15, 1950, by the Citizens Budget Commis-

sion. This proposal involved a dam or so-called barrage across the Hudson River near the City's aqueduct crossings, raising the normal level to about three feet above mean high tide, thus cutting off tidal intrusion, and containing gates for a flood discharge of 300,000 cfs and navigation locks. This plan included low-lift pumps to a filtration plant and high-lift pumps to force 500 mgd into the existing deep-rock tunnel section of the Delaware Aqueduct.

The making of such a connection to the Delaware Aqueduct would require the unwatering of the tunnel and its complete shutdown for at least six months. This would be entirely impractical, due to the City's need of Delaware and Rondout water. The construction of such a dam across the Hudson would involve many uncertain items of great expense and also indeterminate, but undoubtedly large, claims for damages all along the river upstream. The 4-track main line of the New York Central Railroad is located along the east bank with but little elevation above high water over most of its length and would be seriously affected. This proposal was promoted and fully discussed in testimony at the Board's hearings in the spring and summer of 1950 before the State Water Power and Control Commission, at Delhi, N. Y., resulting in an adverse decision.

The Hudson River as a possible source for New York City was more effectively publicized through its recommendation by an Engineering Panel on Water Supply, which was engaged by a Subcommittee for Water Supply of the Mayor's Committee on Management Survey, appointed January 10, 1950, to conduct a comprehensive survey of all city departments and agencies. The Panel was made up of four eminent consulting engineers, the Chairman being Thorndike Saville, a member of this Association. They presented a forceful argument that "Substantial economies may be achieved when the consumption begins to exceed the safe yield of an upland source derived from reservoirs by developing an auxiliary source which may be used to supplement the upland source in those infrequent periods of severe drought when the regulated stream flow approaches the safe yield."

Briefly stated, the writer's studies of the economics of the situation indicated that, considering all phases that are necessary to put the estimates on a comparable basis and even neglecting a number of imponderables which weigh heavily against the Hudson River source, the

early cost differential in favor of the Hudson rapidly disappears and the two projects, compared on the basis of present worth, are just about equal in 35 years, with the Cannonsville Project on the Delaware gaining rapidly with the passing of time.

The report of this Engineering Panel was made July 1, 1951, to the Mayor's Committee on Management Survey and published under the caption "Future Water Sources of the City of New York." The subsequent report of the Subcommittee itself was divided into a majority report by four and a minority report by two of its members. It is important to note, however, that they all agreed that the City should continue the promotion of its petition before the Supreme Court for an additional early supply from the Delaware River. The majority report was passed along by the Mayor's Committee and three of its recommendations were: "that the Board of Water Supply immediately engage a staff of independent consultants and engineers to undertake an impartial study and analysis of the Hudson River as a major water supply source other than on an emergency basis, . . . that the Board of Water Supply undertake the making of preliminary plans and estimates for a modern filtration and treatment plant designed to process the total water supply of the City, . . . that the Cannonsville project be carried forward by New York City."

On the other hand, the minority members of the Subcommittee, whose opinions finally prevailed, made special reference to recent findings made by the State Water Power and Control Commission, to which Commission the Board must in any event apply for approval of the development of any new sources. That Commission had called particular attention to the questionable character of the Hudson River source.

The minority report of the Subcommittee also referred to a previously expressed opinion of the Subcommittee itself: "We are not convinced that even the best water treatment technically available will satisfy the exacting requirements as to taste, quality and other imponderable and psychological aspects to which the public of this City is accustomed. Those who live here, and those who visit here. like our upland water. This is not an advantage enjoyed in other large cities which depend on heavily treated river or lake water."

The minority report concluded: "With such deference to the

ability and sincerity of our consultants, they do not, and perhaps should not, deal with certain realities which is the job of our lay Committee. As to that I grant public opinion is reconciled to use of Hudson River water under emergency conditions, but respected opinions to the contrary, I am convinced that to advance the Hudson as a regular source of supply—even of limited scope and after being subjected to the safeguards under discussion—will engender dire psychological reactions. Why create this condition, and to my mind be still taking serious chances with public health, when more upland sources are still available? Can we deny that if it were not for the much disputed dollar savings involved in the discussion, there would be no reason to consider the Hudson source at this time?"

The Mayor's Committee on Management Survey, after receiving these majority and minority reports of its Subcommittee for Water Supply, reported on April 9, 1952. Its recommendations followed the majority rather than the minority opinions as above expressed. However, the Mayor's Advisory Board of Management Improvement received the report of his Committee on Management Survey and on October 29 rejected that Committee's recommendation for the employment of outside consultants to study the Hudson River source. The Mayor concurred in this rejection and forwarded to the Board on November 7 the directive under which the Board is now continuing to promote its case before the Supreme Court for the extension of its sources to the West Branch of the Delaware River, while at the same time it continues its study of the Hudson River and the possible necessity of future filtration of the entire supply. In rejecting the Hudson-supply recommendation, the Mayor's Advisory Board called attention to a number of pertinent considerations:

> *First*: ". . . It is the duty of the Board of Water Supply to ascertain the best sources for an additional supply of pure water. In fulfilling that duty, the Board is directed to make such studies and investigations as it may deem proper in order to ascertain the facts as to such sources. To that end the Board of Water Supply maintains a capable staff of engineers which has devoted many years to the consideration and development of sources for an additional supply of pure water needed by the people of the City. As a result of its studies the Cannonsville project on the West Branch of the Delaware was recommended by the Board of Water Supply and approved by the Board of Estimate and the State Water Power and Control Commission."

Second: "The desirability of obtaining pure and wholesome water from upland sources has long been recognized. The Supreme Court of the United States in *Connecticut* v. *Massachusetts*, 282 U.S. 660, said, at p. 673: 'Drinking and other domestic purposes are the highest uses of water. An ample supply of wholesome water is essential. Massachusetts, after elaborate research, decided to take the waters of the Ware and Swift (tributaries of the Connecticut, an interstate stream) rather than to rely on the sources in the eastern part of the Commonwealth where all are or are liable to become polluted.' Later, in the case of *New Jersey* v. *New York*, 283 U.S. 336, respecting the diversion of waters from the upper Delaware by the City of New York, the Supreme Court affirmed the conclusion of the Special Master in that case that the higher quality of the waters of the upper Delaware and the advantage of gravity transmission warranted the City in tapping that source of supply."

Third: "The reasons for selecting upland water in preference to the practice of filtering polluted water are obvious. It has been known for many years that typhoid, dysentery and cholera are water-borne diseases. More recent knowledge points to the possible existence of many other diseases, such as viruses. It has never been demonstrated that viruses are removed by filtration of polluted water. The safe procedure is to avoid contact with sewage, since the direct introduction of sewage into a water treatment plant is a potential hazard to the welfare of the community. Even if the water be made bacteriologically safe, such drinking water is, nevertheless, a manufactured product and is actually 'purified sewage' to a greater or less degree."

Fourth: They noted particularly a discussion in the September, 1931 JOURNAL of the Association by Solomon M. Swaab, Consulting Engineer, a witness for Philadelphia in the earlier court case: "Not alone to satisfy esthetic conditions, but also because of human frailties and because no mechanical apparatus can ever be said to be perfect, water used for domestic purposes should come from unpolluted rather than polluted sources. Purification processes have been so highly and exquisitely and scientifically developed as to permit water which has been repeatedly contaminated, purified and used, to be drunk with comparative safety, as far as we know. Undoubtedly, this is not as it should be. Like the process sometimes figuratively called 'sitting on a volcano', it is, or may be, fraught with extremely calamitous consequences. . . . No degree of treatment to which waters can be subjected can ever remove from them the taint lying in the fact that they have passed through the human intestinal tract and that, as they are delivered to the people, they have simply been reconditioned. This idea must necessarily be so revolting to the public taste and so gross a perversion of what, it is generally considered, the public is entitled to, that it must ultimately demand and receive water which has not been defiled. Undoubtedly, it is true, as Master Burch, in the Delaware River case, said, after hearing the testimony, that 'The modern tendency is to obtain for municipal supply the purest water possible and to make this water better, and not to obtain less desirable water

and render it acceptable to treatment and purification, though insuperable economic conditions frequently compel the latter course'."

Fifth: They noted that the State Water Power and Control Commission, approval of which is required on all plans for additional water supply, stated in approving the Board's application for a temporary emergency supply from the Hudson near the Delaware Aqueduct crossing at Chelsea: "The physical and sanitary quality of the Hudson River water at this location (Chelsea) is unsatisfactory for continued domestic use. Its use as a supply of water for public consumption can be countenanced only because of the existing water supply crisis in the City and then only after elaborate treatment and adequate dilution with other waters from the City's present upland sources of supply. . . . If this application were made by the City for approval of the use of the Hudson as a permanent source of supply, it is very doubtful whether the Commission would approve of it even with the treatment now proposed."

Sixth: They noted that the Commission stated in approving the Board's application for the additional supply from the West Branch of the Delaware River: "The City, by various expert witnesses it produced at the hearing, conclusively has shown to the satisfaction of the Commission that the plan proposed for use of the Hudson River would be uneconomical, the cost of construction of such a development, including damages caused thereby, greatly exceeding the cost of the project now proposed by the City, and the annual cost of the operation and maintenance of the Hudson River proposal much greater than that of the Cannonsville project. In addition, it has been shown that raw water from the Hudson River is far inferior in quality to that from the West Branch of the Delaware River and even if it were afforded complete and elaborate treatment, Hudson River water would still be of questionable physical character. The best sanitary engineering practice, and one adopted by the Special Master and the Court in *New Jersey* v. *New York*, 283 U.S. 336, is to obtain the purest water possible for a municipal supply and to make this water better and not to obtain less desirable water and render it acceptable by treatment and purification."

As to the importance of public opinion, note that the Special Master in the Massachusetts-Connecticut case found that "Our governments in the long run are controlled by public opinion. And while an expert on water, acting in a strictly professional capacity, may say that he will disregard public opinion, municipal and other governments cannot take that stand." The consideration of quality, together with public opinion on this point, is the crux of the entire matter, in spite of the fact which is generally admitted, and which is even urged by many competent and highly qualified engineers who have had much to do with water treatment, that it is possible, theoretically and

by the exercise of eternal vigilance, to convert polluted, even grossly polluted, water into a satisfactory and even an attractively clear and sparkling beverage.

We must also consider that there are modern trends in the use of water by industries which discharge into already polluted streams, and in ever-increasing quantities constituents which produce tastes and odors very difficult to treat. Furthermore, there is a constant danger of mechanical breakdowns or personnel lapses, allowing the entrance of bacterial or chemical pollution. As recently as in 1952 the press reported that a quantity of highly poisonous cyanide compound was accidentally spilled into the Delaware River, necessitating the frantically prompt shut-down of several water-supply plants with intakes from the river.

It has not yet been proved that the most complete treatment and filtration, operating perfectly, are a complete defense against some insidious and dangerous viruses, to say nothing of such accidental virulent poisoning as above noted. We do not need to envisage an atomic war to appreciate the advantage of multiple, scattered upland sources, since we can expect industries along the larger rivers to discharge radio-active wastes in increasing quantities.

Boston's experience with long-term storage in upland reservoirs has demonstrated their efficiency in the destruction of bacteria, the bleaching of color and the settling and disposal of undesirable solids. In fact, although Boston, like New York, has contemplated the future necessity of filtration of the entire supply and has planned a definite site for such filters, the upland supply after storage continues to be of such excellent quality that filtration details have never reached the detail planning stage.

The conclusion is inescapable that large coastal cities like New York and Boston, located near well-watered areas of rugged upland topography, are in a fortunate position, in so far as their ability to obtain raw water not grossly contaminated is concerned. They are simply lucky and are not in the market for a water supply from increasingly polluted sources. That is why New York is pushing its case before the Supreme Court and hopes for a favorable decree.

Conclusion

Although, as previously stated, it is not appropriate to discuss the merits of New York's case while it is still before the Special Master and the Court, attention is called to a statement regarding the litigation, which was authorized by counsel for all parties to the case and released by Mayor Impellitteri June 22, 1953. The following quotations from this statement speak for themselves:

"In August an inspection trip was undertaken by the Special Master, engineers and counsel for all the parties. This trip, lasting five days and including an inspection of the dams and works under construction on the Neversink River and the East Branch of the Delaware, extended the full length of the river down through the estuary to Wilmington.

"During the ensuing months further pre-trial conferences were held, in the course of which exhaustive engineering studies and other data prepared by the Board of Water Supply of New York City were made available to all parties. The written testimony and exhibits representing New York City's affirmative case were circulated among the other parties for study and preparation of cross-examination. Thereafter, extensive engineering studies made by the New Jersey and Pennsylvania engineers were exchanged.

"As a result of these pre-trial conferences and the opportunity for studying the detailed proof afforded to counsel and engineers for the respective parties, the issues have been narrowed to a point where it is now possible for all parties to make certain recommendations to the Special Master. These recommendations should materially shorten the hearings and expedite the ultimate determination of the case. Accordingly, it has been agreed among counsel that the following proof shall be presented:

"1. By New York City in support of its request to have the injunction limiting its withdrawal from the Upper Delaware modified to permit it to withdraw 490 million gallons daily instead of 440, pending the construction of a new reservoir at Cannonsville, and thereafter 800 m.g.d. These diversions are subject to the basic requirement that there must be released from the New York reservoirs on the Upper Delaware during the dry summer and fall months, water

sufficient to maintain the flow of the Delaware River at the gage now located at Montague, New Jersey, (a) at not less than 1,525 cubic feet per second, pending the completion of the Cannonsville project, (b) at not less than 1750 c.f.s. after the completion of the Cannonsville project There is also the further requirement that, in addition to these quantities, there shall be released 83% of the difference between the consumption of water by New York City and the total safe yield of New York's entire water supply system without pumping.

"(New Jersey and Pennsylvania have maintained that New York is exaggerating its future water supply needs. New York maintains that its estimate of future needs is a prudent one. However, the agreement to release 83% of any difference, so long as it exists, between the safe yield of New York's entire system without pumping and its actual consumption gives to Pennsylvania and New Jersey for the improvement of the lower river in the summer and fall months the benefit of any excess in the claims New York is making.)

"In consideration of the increased capacity of the lower basin resulting from the modified release formula thus offered by New York, New Jersey and Pennsylvania will not oppose the proposed diversions by New York.*

"2. By New Jersey in support of its request to be permitted to divert 100 m.g.d. without obligation to release any compensating water. (This 100 m.g.d. would be diverted through the Delaware and Raritan Canal which has been in use, and through which water in varying quantities has been diverted, for more than 100 years.) Pennsylvania will not oppose this traditional use by New Jersey. New York State and New York City are not affected by the diversion through the Delaware and Raritan Canal.

"New Jersey is to enact legislation which will remove the present legal obstacles to the erection of reservoirs by Pennsylvania on the main channel of the Delaware River. (Not yet enacted, before adjournment of the 1953 session in June.) Such legislation is to provide that New Jersey may participate in the use of any storage dam erected by Pennsylvania to the extent of not more than 30% upon paying a

* *Editor's Note*: An amended decree, granting New York's request for 800 mgd, was handed down by the U.S. Supreme Court June 7, 1954.

proportionate part of the cost of the reservoir, and that New Jersey agrees to exercise for Pennsylvania's benefit and at Pennsylvania's cost, the right of eminent domain to make possible the construction of storage or diversion dams across the river.

"3. By Pennsylvania setting forth its estimated future water needs from the Delaware River basin, the various alternative methods by which its needs could be met, the present sources of water supply of the City of Philadelphia and the necessity for removing certain existing legal obstacles to the development of water works in the main channel of the Delaware for the use of southeastern Pennsylvania.

"4. Pennsylvania insists, and New York and New Jersey concede, that the modified decree of the Supreme Court should continue its existing provisions that the takings by New York and New Jersey shall not be deemed adjudications in perpetuity of the fair and equitable shares of New York and New Jersey of the water of the Delaware River and that no party shall be estopped from asking for a review of the terms of the decree to be entered. . . .

"The capacity of the Delaware River during the periods of low flow will be substantially improved through the compensating releases which New York will be required to make. The proposed New York developments are so designed that the catchment of water for storage will take place primarily during flood flows and the releases to the lower river will occur during the dry months of summer and fall. The formula governing the New York works insures a timely and beneficial distribution of the water released to the lower river.

"The removal of the obstacles to the construction of reservoirs or dams on the main channel of the Delaware will greatly expedite the building of any water supply works on the Delaware or its tributaries if and when they are needed.

"In flood times, there is more than enough water in the Delaware for everyone. In seasons of abnormally low flow, the releases which New York has agreed to make will be a great boon to the Lower Delaware. In the opinion of the engineers for Pennsylvania and New Jersey the additional diversion by New York City under its enlarged plan of development will, if conditions do not change, have no adverse effect on the interests of Pennsylvania and New Jersey, but on the

contrary will further such interests by increasing the quantity of water available to those states."

At the same time of this release the Mayor included a pertinent statement of the factual background, from which the following is quoted:

"This case has actually been pending for more than a year. It has, however, been in preparation for more than six years. The Special Master, Hon. Kurt F. Pantzer, was appointed by the Supreme Court of the United States in June 1952 to hear the case and report his recommendations to the Court. He has from the very first urged negotiation of the differences between the parties. It was his belief that a more effective use of the river could be obtained through an exchange of information, testimony and exhibits and through conferences of counsel and engineers than would result from the normal procedures of litigation. The representatives of all of the parties have endeavored at many meetings during the past several months to comply conscientiously with the Master's desires.

"These negotiations have resulted in what I believe is the very substantial accomplishment set forth in the joint press release. This reflects very definite clarifications of complicated engineering details and the narrowing of legal issues to be determined by the Special Master and the Supreme Court. . . .

"The opposition of New Jersey and Pennsylvania centered around their fears that the taking of the additional water by New York would leave too little water available in the lower river for the domestic and industrial water supply needs of communities along the river. These communities have been growing rapidly. The advent of the Fairless Works of the United States Steel Corporation at Morrisville, and the extensive residential and business developments adjacent thereto, will probably require Philadelphia to take its domestic supply of water from the river at a point north of Trenton. It was also feared that the proposed increased diversion by New York could cause the 'salt front' in the bay to move upstream towards Trenton Falls, with possible damage to the industry along both sides of the river below Trenton. New York experts' testimony in this case has demonstrated that these fears are groundless.

"New York at all times has taken the position that the objections of Pennsylvania and New Jersey could be overcome by an improved release of water from the City's reservoirs on the Delaware tributaries so as to increase the flow of the river during the summer and fall months, when the natural flow is normally very low. The Supreme Court has established the principle that, as a condition to the taking of water from the Delaware River and its tributaries, releases of compensating water must be made during periods of low flow in the stream. Accordingly, it is New York's plan to impound water in its reservoirs during the flood stages of the river in sufficient quantity to give New York City 360 million gallons daily of additional water and at the same time to permit the release of water during periods of low flow, so that the conditions of the lower river will be improved when they most need such improvement.

"As a result of the negotiations, a formula for the release of waters for the City's developments on the Delaware tributaries has been worked out. This formula does not involve any change in the City's original plans concerning the dam and reservoir near Cannonsville or any increase in its storage capacity. No additional cost to the City is involved. The formula provides a more effective use of the waters stored for release purposes by changing the timing of the releases. . . .

"The improved formula which accomplishes the above purposes will be put into effect by New York if it meets with the approval of the Special Master and the Supreme Court. Throughout the entire proceeding, the State of New York has consistently coöperated with the City and supported the City's position."

DOMESTIC AND INDUSTRIAL WATER SUPPLIES FACE THE POLLUTION PROBLEM

BY MALCOLM PIRNIE*

[*Read September 30, 1953.*]

Without doubt each of you has seen recent references to the fact that the desert rat does not need to drink water. If each of us were equipped with the remarkable facility of the desert rat for separating the hydrogen from the carbon in foods and then combining it in the correct proportion with oxygen from the atmosphere, the word "domestic" could be stricken from the title of this paper. Of course this accomplishment makes the rat a tempting target for all thirsty predatory animals, which know they can depend on the rat for a good drink.

Our own domestic water supplies are similarly tempting to industries seeking to locate in areas with good resources of all kinds. Some years ago, for example, my firm studied and reported on some eleven sites throughout the southeast as possible locations for a large paper mill, requiring huge volumes of water. Some of these were ruled out because of high costs, others because of poor-quality natural water or lack of suitable waters to receive the liquid wastes. But the one that was selected had a potential source capable of supplying not only the large demand of the mill itself, but also the projected demand of 80,000 persons, which has since grown to that of well over 100,000 persons.

This industry, in seizing upon a large source of unpolluted water, has unquestionably benefited its new neighborhood. So it is easily demonstrated that it is to the benefit of the community to face up to its water-supply problems and meet its pollution problems head-on.

Pollution problems may be the same for municipal plants as for industrial plants or they may be dramatically different. A paper-mill client of ours, which makes the familiar green and black, two-sided

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backing papers for photographic films, not too long ago had to reject a complete run of this specially processed, expensive paper. Why? Because something that had never before happened to its Adirondack Mountain water supply had made its paper unsuitable for photographic uses. Dust from the atomic explosions in Nevada had been precipitated from the skies over the Adirondacks by snow that had melted and made the water, and hence the paper, radioactive.

Another modern trouble has appeared to annoy the water-works operator. For some time now we have been treated with newspaper photographs of mountains of foam on, or sailing through the air from, sewage-treatment plant aeration tanks and have grinned to ourselves at the plight of our brother sewage-works operator. But then the blow fell! The detergents, largely unaffected by their passage through sewage-treatment plants, entered water-treatment plant intakes, causing lime, coagulants and natural turbidity to carry through the settling basins, thus dangerously reducing filter runs and introducing objectionable tastes in the finished water.

Down in New Jersey there is a small river, which used to furnish pretty good fishing and swimming for the rural communities along its banks, even after a yeast plant was built upstream. Then, some twelve years ago, a paper plant a little farther upstream commenced discharging its wastes. The fish vanished and the stench was so strong that it was common gossip that motorists took long detours to bypass the shores of the stream. This was not a water supply, except in the sense that it supplied a recreational facility. And yet it represents an extreme of the influence that pollution may have on the general public.

Another possible extreme of much grimmer portent is the problem recently faced twice by the city of Philadelphia. Once a wrong valve was opened and another time a lagoon dike was breached, but in both cases deadly amounts of cyanide were discharged into the Delaware River above Philadelphia's Torresdale intake. Fortunately in each case an employee of the chemical and plastic company where this occurred reported the accident to his superior, who immediately notified the Philadelphia authorities. The first time, one-ton containers of chlorine were quickly brought to the river intake and their discharges placed directly in the river. The second time there was

greater river flow, and the tide changed just as the poison approached the intake and pushed it back upstream. By the time it came downstream twelve hours later, it had been diluted enough for normal plant treatment to take care of it. Suppose that first operator had not admitted his mistake!

Assistant Surgeon-General Mark Hollis aptly stated the problem in a recent paper: "It has been a basic error to separate the need for a safe drinking water supply from the need to prevent gross pollution of the raw water source."

This is at odds with a statement in a current periodical by a spokesman of the chemical industry. He says, "Stream pollution abatement *is* primarily a matter of esthetics and conservation."

He goes on to point out that epidemiological evidence is lacking to prove the threat of stream pollution to public health or, more specifically, a connection between such diseases as poliomyelitis and water-borne pollution.

What troubles me about these statements is not the lack of proof, but the lack of willingness to bend every effort toward the elimination of any factor which might possibly adversely affect the health of those millions who so unthinkingly and trustingly drink the water we furnish them.

When I first went into this business viruses were not even a theory. Today we know the polio virus appears in sewage. Does it ever get through our treatment plants?

Researchers have found a virus which in mice will cause cancer of the salivary glands. Do similar viruses ever pass through our treatment plants?

Every year there are gastro-intestinal outbreaks which are best explained by being water-borne. Yet there appears to be adequate treatment of the water served to the people affected.

I bring up these things merely to point out that, in spite of modern scientific progress, we don't know all the answers and that we must practice eternal vigilance.

The backlog of proposed water-works construction projects is estimated today at $1.4 billion. The backlog of sewerage projects is estimated at $2.4 billion, and a ten-year program of investment in treatment facilities for municipal and industrial wastes is estimated to require $9 to $12 billion.

A notable example of how one city and a polluting industry profitably licked their joint problem is that of Richmond, Va., and the West Virginia Pulp & Paper Co. It was some years ago, when the city of Richmond was experiencing considerable difficulty with offensive tastes and odors in its James River treated water, which were traced in part to the effluent from a mill of the West Virginia Pulp & Paper Co. many miles upstream. The company, always co-operative and progressive, agreed to join with the city in an effort to find out how best to combat the trouble. It agreed to eliminate as much as possible of its wastes from the stream and the city agreed to experiment with improved treatment facilities and taste-controlling agents. In carrying out its part of the promise, the company found that it could evaporate its black liquor and convert the residue into porous charcoal by passing it through kilns, and valuable process chemicals were leached from the charcoal. In turn the city found that it could use the powdered leached charcoal for controlling the taste in the water; and from that beginning we have today one of the most effective taste- and odor-controlling materials, "Nuchar," as produced by the Industrial Chemical Sales Division of the West Virginia Pulp & Paper Co. This was a successful solution of a tough problem.

The city of Watertown, N.Y., has not yet found the solution of its problem. There, a latent, medicinal or iodoform taste becomes obnoxious and objectionable at irregular and widely separated intervals. Surveys upstream and close inspection of plant operating records have yet to reveal a correlation of events which would permit diagnosis of the trouble. Yet it is there—and although I have named but one town, I know each of you could name several where similar conditions occur. Is this a pollution problem? Or is it some condition in the natural water about which we do not yet know enough?

I was intrigued by a small piece in the paper a couple of weeks ago, which reported the research of a group of doctors on a small group of persons and which purported to show that over 90% of them had accumulations of DDT in their fatty tissue. These accumulations were nowhere near the danger mark, but the doctors raised the question of what would happen to our population 10 or 15 years from now, with increasing use of accumulative poisons.

These persons undoubtedly received some of their DDT from foods they had eaten. We have no way of knowing today whether significant amounts of it may be washed into reservoirs and other water-supply systems. Some water works have asked other utilities to refrain from using certain weed killers on their catchment areas, fearing the ultimate effect they might have on quality of the water. But not too many of us have such complete control of our catchment areas that we can do this. Unlike the argument which prevails over the use of fluorides and their ultimate effect on the population, the one centering around the use of poisons within the watershed, some of which we know are as accumulative in their actions as arsenic, should give us cause for thought.

Since Benjamin Rush first attacked filth in Philadelphia, we have made great strides. However, we should not let the great strides of the past blind us to the new problems and those still unsolved and confronting us in water treatment. As our industrialization progresses, problems become more acute. The wastes from one industry will affect the treatment plant at another. And the wastes from both combined will produce organic compounds and resulting tastes and odors, incapable of treatment by presently known methods, in the municipal filter plant downstream.

We have nearly banished distinctive micro-organisms from our domestic water supplies. We must not be content to use methods that accomplished this in treatment of waters receiving wastes from various industries, one or a combination of which may prove destructive of health before the danger is suspected. The prize portions of catchment areas for domestic water supplies are still the upland areas, developed with storage reservoirs or natural lakes. From them, even today pure water can be delivered anywhere on a consumer's premises for two to seven cents a ton—a cheap essential in our present standard of living, compared with a roast of beef at $1.00 a pound.

Facing the uncertainties of anticipated future and even existing pollution problems, fortunate indeed is the community able to reach out for an upland supply devoid of such problems. The rest of us must constantly strive to lessen the pollution load reaching our plants and to treat adequately all that does.

SIGNIFICANCE OF THE COLIFORM TEST IN RELATION TO INTESTINAL VIRUS POLLUTION OF WATER†

BY F. W. GILCREAS AND SALLY M. KELLY*

[*Read September 30, 1953.*]

The significance of the numbers of colon bacteria in water as an indicator of pollution has been generally accepted since its initial suggestion by Dr. Theobald Smith in 1890 (1). Apparently the first use of a colon bacilli index in determining the quality of water was made in connection with a survey of the Mohawk and Hudson Rivers undertaken by the New York State Board of Health in 1892 (2). Since that time such an index has been the standard measure of sewage pollution of water, although our ideas of the significance of these microorganisms have undergone revision throughout the years. Each edition of *Standard Methods for the Examination of Water and Sewage* (3) has introduced changes in technic which have broadened the scope of what is termed the "coliform group" by the inclusion of additional bacteria similar in cultural characteristics. While originally the technics were developed for the isolation and enumeration of colon bacilli believed to originate in the human intestinal tract, modifications were made to include the aerogenes groups and other intermediate forms, with the result that now the coliform group is an indicator not so much of intestinal pollution of a water supply as of the presence of sewage and undesirable contaminants.

The coliform group has proved to be an excellent criterion of water quality; its continuous use and the liberalizing of the interpretation of the results have led to marked improvement in water quality. Especially is it an excellent measure of the amount of sewage pollution in a water supply and a guide to the efficiency of various water treatment procedures. The coliform index, however, does not necessarily reveal the presence of pathogens of intestinal origin in water and there-

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fore does not indicate the potential danger to a consumer who uses the supply.

From time to time there have been demands for the development of a new indicator of significant water pollution, one which would be intimately concerned with the potential disease hazards in the use of the water as well as being a measure of water quality. The question has frequently arisen—does the coliform index actively and accurately measure pollution by microörganisms other than those associated with the usual forms of enteric disease, such as dysentery or typhoid fever? Epidemiologic evidence often points to a water supply as responsible for an otherwise inexplicable outbreak of intestinal disease, although repeated bacteriologic examinations have failed to show the presence of significant densities of coliform bacteria. Development of a new index is based upon the need for a quantitative indication of other types of intestinal pathogens.

Attention is necessarily focussed upon the significance of viruses as incitants of disease and whether or not their determination in water would be a measure of the safety of a supply for domestic use. Evidence that standard types of water treatment eliminate viruses in the same ratio as they eliminate bacterial agents of disease is fragmentary.

Few viruses have been incriminated as water supply contaminants. Poliomyelitis virus has been isolated from creek water (4). Hepatitis virus has been isolated from well water (5), and outbreaks of hepatitis have been traced epidemiologically to contaminated water supplies. Volunteers have been shown to develop hepatitis from drinking water inoculated with the virus (6). The accusation of these viruses as possible water contaminants is based mainly on their numerous isolations, poliomyelitis in particular, from sewage rather than from actual water supplies. Since, however, sewage may contaminate water supplies, attention directed toward virus control in either sewage or water treatment is justified.

Water treatments that have been critically examined by previous investigators for their ability to inactivate viruses are storage (7), chlorination (8), heat (9), ultraviolet irradiation (10), coagulation (10), sedimentation (11), and filtration (10). These studies, while valuable for their information on virus behavior under these condi-

tions, were done without reference to the effect of such treatments on coliform bacteria, the microörganisms on which the present standards of water purity are based.

In order to determine if various types of water and sewage treatment are as satisfactory in eliminating viruses as bacteria, the comparative survival of coliform bacteria and viruses in water under several environmental and water treatment conditions was studied. Such conditions as reservoir storage, laboratory storage, storage in different water types and at various pH values, and the effects of chlorination, temperature, and exposure to ultraviolet light were investigated.

The bacteria chosen were coliform microörganisms, represented chiefly by *Bacterium coli* 3635, a strain maintained in this laboratory for 15 years. The virus selected was *Bacterium coli* B bacteriophage, since it is a virus enteric in habitat and easily detectable by quantitative tests. Selected survival experiments were done with stock mouse-leg suspensions of Coxsackie virus Group A types and with mouse-brain suspensions of Theiler (T.O.) virus to provide a comparison with viruses that are animal pathogens as well as enteric in nature. Naturally-occurring coliform bacteria, *Bact. coli* B bacteriophage, and Coxsackie viruses were studied for their survival during various stages of sewage treatment.

Assay Methods

Coliform bacteria were determined by plate counts on tryptone agar (12a) of ten-fold serial dilutions of 1-ml. aliquots in triplicate. Occasionally, most probable numbers of microörganisms per 100 ml. (MPN) were determined also by inoculation of ten-fold serial dilutions of 1-ml. aliquots into 5 lactose fermentation tubes, followed by confirmation in brilliant green bile broth (12b).

Bacteriophage was measured by counting the plaques formed by 1-ml. aliquots on crystal violet agar plates in triplicate seeded with *Bact. coli* B as host (13).

Theiler virus measurements were determined as the median effective dose* required for limb paralysis in 10-12-gram mice during 21-30 days following injection intracerebrally with Theiler-virus-containing suspensions. Coxsackie virus was determined as the median effective

* Median effective dose determined by moving-averages method of Thompson (12c).

dose required to produce limb paralysis in 3-day-old mice during the 10-14 days immediately following intraperitoneal injection with Coxsackie-virus-containing suspensions.

Water Sources

Most of the experiments, as indicated below, were carried out in spring water. Unless otherwise noted, all waters used were sterilized by autoclaving for 15 minutes to eliminate other microörganisms that might interfere with the methods of assay. While this treatment no doubt made changes in the state of dissolved materials, in mineral and organic matter and in dissolved oxygen content, particularly, it was assumed these had little influence on the outcome of the relative survival studies.

Survival During Storage in Reservoir

Comparative survival in reservoir storage was determined as follows: Two-liter amounts of autoclaved spring water in glass-stoppered Pyrex bottles, which had been allowed to come to temperature equilibrium for 24 hours previously in the reservoir, were inoculated with *Bact. coli* B bacteriophage at concentrations of approximately 10^5, 10^6, and 10^7 particles per ml. or with an 18-hour broth culture of *Bact. coli* 3635 diluted to give approximately 10^2, 10^3, and 10^4 colonies per ml. Three 1-ml. aliquots of each inoculation for determination of initial numbers of microörganisms present were taken immediately before the inoculated bottles were placed in the reservoir. The bottles were protected by water-tight stainless-steel pails, weighted with lead to keep them submerged.

The reservoir consisted of spring water stored in a submerged concrete tank 6 x 3.5 x 4 feet with a capacity of 629 gallons. The tank was within four brick walls covered by a sloping roof 6-10 feet above the water level.

Aliquots were removed from the inoculated bottles at weekly intervals for 6 weeks and then monthly, to determine the number of surviving organisms of each type. From these determinations the per cent survival from the initial count was calculated. Temperatures during the storage period were measured on maximum-minimum thermometers. Dissolved oxygen in the bottles was determined during the

first few weeks of storage. Since there was no detectable difference in the rate of oxygen depletion in the test samples, it appeared that the amounts used by the two types of organisms in this experiment were the same and thus this measurement was discontinued.

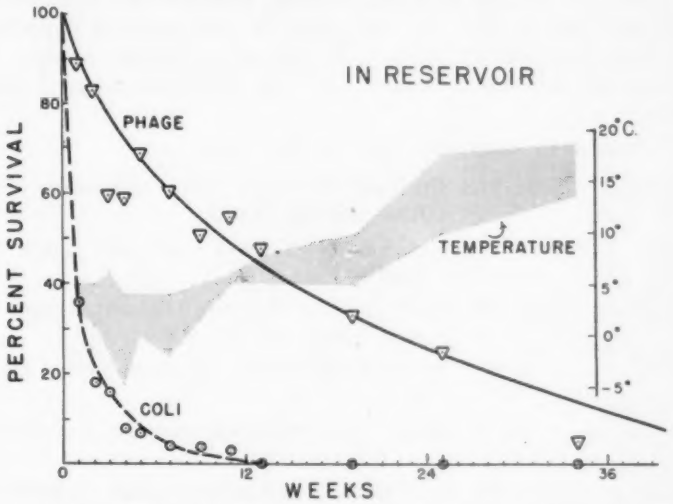

FIG. 1.—RELATIVE SURVIVAL OF *Bact. coli* 3635 AND *Bact. coli* B BACTERIOPHAGE UNDER RESERVOIR CONDITIONS, JAN.-SEPT., 1952.

As indicated in Figure 1, the survival of phage was greater than that of coliforms. Not only was the rate of phage survival greater but its persistence longer. The temperature changes that occur during the storage period are probably not the cause of killing, since the rate of decrease is not proportional to the temperature change. This experiment was repeated over a shorter interval; the results were similar to those in the preceding experiment.

SURVIVAL DURING STORAGE IN THE LABORATORY

The experiment described above was repeated, modified to laboratory conditions of cold room storage at 8-10° C. In addition to survival in spring water, storage survival in autoclaved salt, brackish,

river, reservoir, swamp, and hard water and in autoclaved sewage was followed. One-liter amounts in glass-stoppered Pyrex bottles and 500-ml. amounts in rubber-stoppered Erlenmeyer flasks were inoculated with a mixture of *Bact. coli* 3635, approximate concentration of 10^4 cells per ml., and *Bact. coli* B phage, approximate concentration of 10^4 particles per ml. Six 1-ml. aliquots were removed immediately for determination of numbers of organisms initially present. The mixed inoculum was used since *Bact. coli* 3635 is not a host for the B phage.

Sources of water and collection dates are:

Spring:	1/31/52.	Enclosed reservoir, State Laboratory Farm, Voorheesville, N. Y.
Salt:	1/31/52.	Babylon Town Dock on Great South Bay, Suffolk County, N. Y.
Brackish:	1/31/52.	West Creek at Montauk Highway Bridge, high tide, Suffolk Co., N. Y.
River:	1/25/52.	Naval Reserve Pier, Hudson River, Albany, N. Y.
Reservoir:	1/25/52.	Bridge at Tomhannock reservoir, Raymertown, N. Y.
Hard:	1/25/52.	Raw water, water softener plant of Bethlehem Water District No. 1, Delmar, N. Y.
Sewage:	1/25/52.	Settling tank, sewage treatment plant, Watervliet, N. Y.
Swamp:	1/25/52.	Cattail swamp, Route 7, Raymertown, N. Y.

Chemical analyses of these waters are given in Table 1.

Aliquots were removed weekly for six weeks and thereafter monthly to determine the number of surviving organisms in each water type. As indicated in Figure 2, survival of phage was greater and persistance longer than that of coliform bacteria. This was true regardless of water type. Survival and persistence of phage were greatest in river and least in salt water. Coliform survival was greatest in swamp and least in salt water.

TABLE 1.—ANALYSES OF WATER SAMPLES.
(Results in p.p.m.)

Water type	pH	Color	Turbidity	Iron	Phosphates	Total hardness	Free NH_3	Total NH_3	Nitrites	Nitrates	Total alkalinity	Oxygen consumed
Spring	8.9	0	Trace	0.05	<0.5	74	0.004	0.020	0.001	0.5	44	
Salt	9.1	5	25	0.8	<0.5	5220	0.002	0.242	0.001		93	
Brackish	8.5	10	8	0.8	<0.5	1220	0.014	0.182	0.002		26	
Swamp	7.2	5	Trace	0.1	<0.05	26	0.006	0.060	0.001	0.1	15	
River	8.8	20	10	0.35	<0.05	80	0.036	0.154	0.002	0.3	26	
Hard	8.0	0	25	0.03	<0.05	124	0.006	0.008	0.001	2.0	55	
Reservoir	7.6	10	5	0.28	<0.05	32	0.016	0.088	0.001	0.08	20	
Sewage	9.0	2	195		3.4	158	12.5		0.003	0.04	135	178

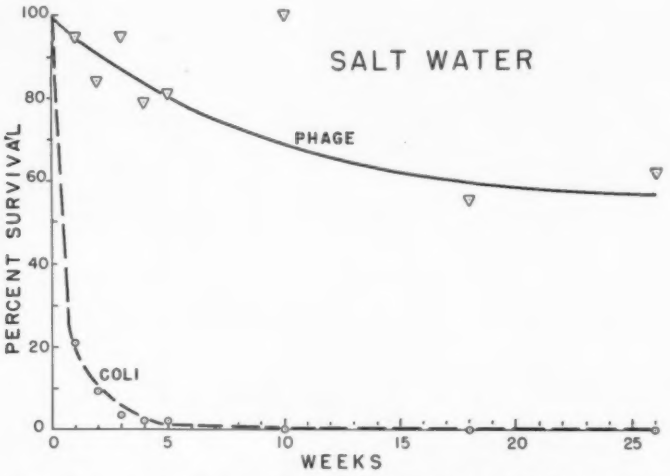

FIG. 2.—RELATIVE SURVIVAL OF *Bact. coli* 3635 AND *Bact. coli* B BACTERIOPHAGE DURING COLD ROOM STORAGE IN SALT WATER.
(Relative survival in the other types tested compares, in general, with that illustrated here.)

Storage of Theiler and Coxsackie viruses in spring water and in autoclaved sewage at cold room temperature was compared with that of coliform bacteria and phage. At 8°-10° C. Theiler virus in spring water (200 M.E.D. M.E.D. = 7.7) and in sewage showed no consistent loss of infectivity during a 4-week storage period, while during the same period, 50-per-cent phage and 1-per-cent coliform bacteria survived. Coxsackie virus (50 M.E.D. M.E.D. = 8.4), similarly, showed no loss of infectivity at cold room temperature during a 3-week storage (Table 2).

A comparison of the survival rates of coliform bacteria in the eight water types examined suggests that three different survival patterns occur in bacteria of the coliform group: i.e., survival in sewage and in salt and river water was exceedingly brief; that in brackish, hard, and spring water somewhat more prolonged; and in reservoir water the coliform microörganisms were able to survive for even longer periods.

TABLE 2.—RELATIVE SURVIVAL OF *Bact. coli* 3635, *Bact. coli* B BACTERIOPHAGE, THEILER VIRUS AND COXSACKIE VIRUS IN WATER AT 8°-10° C.

Week	Per cent survival			
	Coliform bacteria	Bacterio-phage	Theiler virus	Coxsackie virus
1	33	68	16	100
2	10	67	10	
3	1	58		100
4	1	52	100	

The experiment was repeated with new samples of four of the water types: river, salt, and reservoir waters, and sewage, collected between February 25, 1953, and April 2, 1953, and autoclaved before inoculation. Five-ml. portions, inoculated with either coliform bacteria or phage, were kept in screw-capped test tubes and two 1-ml. aliquots removed for determining numbers of surviving organisms. As in the preceding experiment, the survival rate of phage was greater than that of coliform bacteria.

In reservoir and cold room storage, then, the survival rate of bacteriophage and its persistence are greater than those of members of the coliform group. This greater resistance than coliforms to cold is characteristic also of Theiler and Coxsackie viruses.

SURVIVAL AT VARIOUS pH LEVELS

Comparative survival of coliforms and phage was followed at room and at cold room temperatures in spring water adjusted to various pH levels. Spring water buffered with M citric acid and M disodium phosphate to give pH values of from 3 to 8 was inoculated with either *Bact. coli* 3635 or *Bact. coli* B bacteriophage to give approximately 10^4 cells and 10^5 particles per ml., respectively. The suspensions were distributed separately as 10 ml. per screw-capped test tube. One set of tubes was kept at room temperature (23°-29° C.) and a second set in the cold room at 8°-10° C. Two 1-ml. aliquots were removed from each of 2 tubes to determine the number of organisms initially present. Aliquots were similarly removed at weekly intervals for 6 weeks and monthly thereafter. From determinations of the numbers of organisms present the per cent survival was calculated. The

differences in survival rates between coliform bacteria and phage were dependent upon temperature, rather than upon response to pH levels. For example, survival rate and persistence of phage were greater than those of coliforms, regardless of the pH levels, when the organisms had been stored in the cold, a result comparable to that obtained in the storage of microörganisms under reservoir conditions and in the laboratory cold room (Figures 1 & 2).

Survival under Various Environmental Effects

Temperature. Spring water was inoculated with either *Bact. coli* 3635 or with *Bact. coli* B bacteriophage and was exposed to the following temperatures: -55°, 8°-10° (Table 2), 20°-30°, 36.5°-38°, 59°-60°, and 99°C. Survival at -55°C. was studied as follows: 10-ml. amounts of suspension were placed in sterile 1-oz. sputum jars after three 1-ml. aliquots were taken for determination of the number of microörganisms initially present. The suspensions were frozen and kept in a dry-ice chest with a temperature from -45° to -60°C. Jars were removed at 1-, 3-, 12-, 20- and 46-day intervals, allowed to thaw at room temperature, and titrated for final numbers of microörganisms. The survival rate of both types was so low, from 0.1 to 0.9 per cent at the intervals tested, that no significant difference between them was measured.

In the remaining temperature experiments reported, the microorganisms used were, as above, *Bact. coli* 3635 and *Bact. coli* B bacteriophage and Theiler and Coxsackie viruses. The suspensions were distributed at 5- or 10-ml. amounts in sterile 125-by-20 screw-capped test tubes.

Survival at 20°C. was followed by placing tubes containing coliform bacteria at 10^4 cells per ml. and phage at 10^5 particles per ml. in a refrigerator maintained at this temperature. Tubes were removed at 1-, 4-, 9-, 23-, and 45-week intervals, and their contents titrated for final microörganism counts. As indicated in Figure 3, the survival rate of coliforms is greater than that of phage.

Survival of Theiler and Coxsackie viruses at room temperature (20°-30°C.) was compared with that of phage and coliforms. During 3- to 4-week storage in spring water and sewage, Theiler virus infectivity (200 M.E.D. M.E.D. = 7.7) dropped to 25 per cent of the

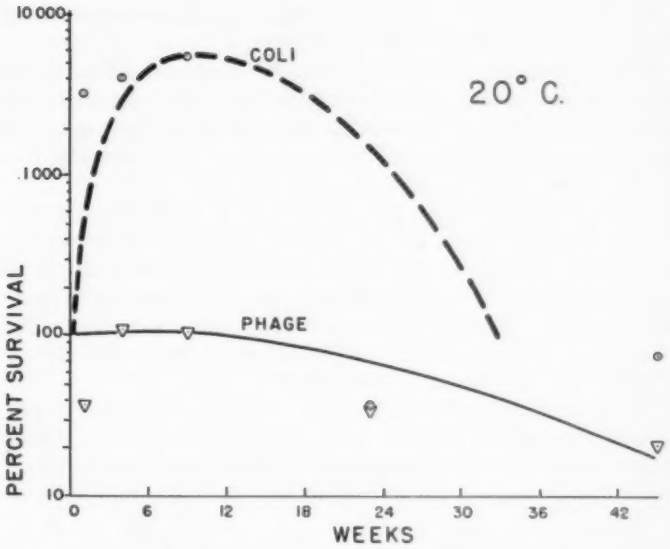

FIG. 3.—RELATIVE SURVIVAL OF *Bact. coli* 3635 AND *Bact. coli* B BACTERIOPHAGE IN WATER AT 20° C.

original. Coxsackie virus (50 M.E.D. M.E.D. = 8.4) showed a 100-fold loss of infectivity. Phage survival in water dropped to 1 per cent and in sewage to 50 per cent during this period; coliform microörganisms in the same interval increased to 1,000 times their original number (Table 3).

TABLE 3.—RELATIVE SURVIVAL OF *Bact. coli* 3635, *Bact. coli* B BACTERIOPHAGE, THEILER VIRUS AND COXSACKIE VIRUS IN WATER AT 20°-30° C.

Week	Coliform bacteria	Per cent survival Bacterio-phage	Theiler virus	Coxsackie virus
1	6,000	48	100	14
2	14,000	11	100	
3	22,600	7		0.36
4	16,600	1	25	

At room temperature, then, the survival rate of phage and other viruses is less than that of coliform bacteria.

Tubes containing 10^4 cells per ml. coliforms and 10^3 to 10^5 particles per ml. phage were also placed in a 36.5°-38°C. incubator. They were removed for determining the final count at intervals from 1 hour to 3 weeks. As data in Figure 4 show, while survival rate of both microörganisms was approximately the same during the first few hours, the coliform survival rate became much greater as exposure to 36.5° to 38°C. temperature continued. Coliform behavior at this temperature, as is well known, is not mere survival but multiplication; for phage, however, this temperature over longer periods is harmful. Phage maintains itself in this temperature range for at least 3 hours, but less than 19 hours. *Bact. coli*, on the other hand, multiplies or at least maintains itself for a 2-week period.

Tubes containing 10^4 cells per ml. coliforms, 10^5 particles per ml. *Bact. coli* B phage, or Theiler virus (4 M.E.D. M.E.D. = 6.4) were placed in a waterbath maintained at 59°-60°C. and tubes removed for determining the final count at intervals of from 1 minute to 4 hours.

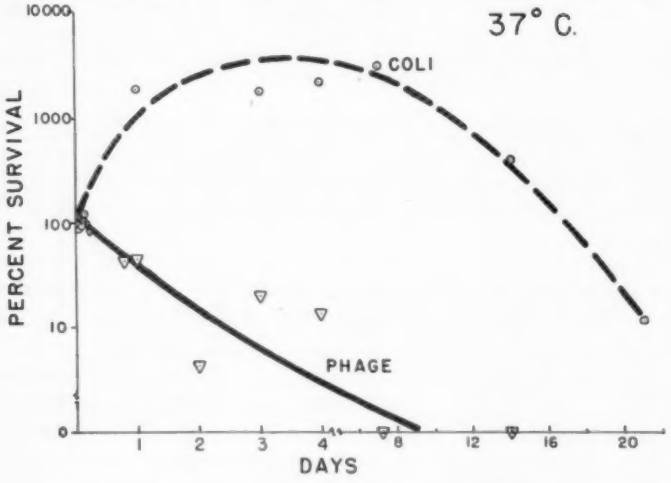

FIG. 4.—RELATIVE SURVIVAL OF *Bact. coli* 3635 AND *Bact. coli* B BACTERIOPHAGE IN WATER AT 37° C.

The survival rate of phage at this temperature exceeds that of *Bact. coli* at all the intervals tested (Figure 5). Persistence of phage was longer also, 20 per cent of the original number of particles remaining after 4 hours, whereas a negligible number of coliforms was left after 20-minute exposure. Theiler virus survival at this temperature was nil.

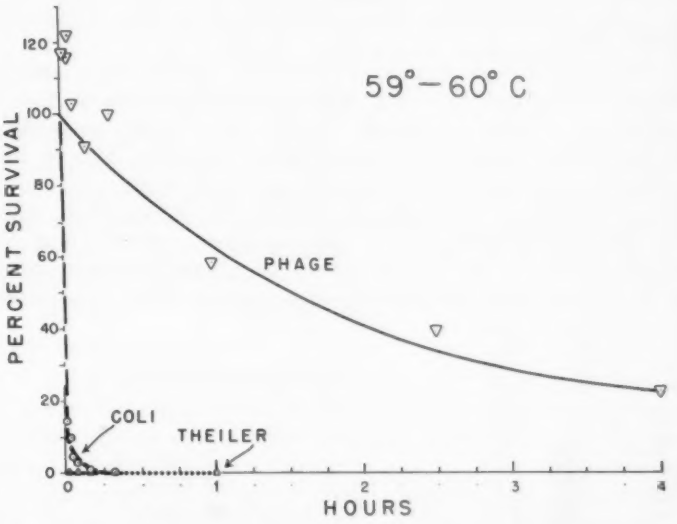

FIG. 5.—RELATIVE SURVIVAL OF *Bact. coli* 3635, *Bact. coli* B BACTERIOPHAGE, AND THEILER VIRUS AT 59°-60° C.

Tubes containing 10^4 cells per ml. *Bact. coli* 3635, 10^5 particles per ml. *Bact. coli* B bacteriophage, or Theiler virus (3 M.E.D. M.E.D. = 6.5) were placed in a boiling water bath and were removed at intervals up to one minute. The temperature to which they were subjected, as measured by the temperature in a control tube, was 99°C. None of the organism types survived even for so short a time as 20 seconds.

This series of survival experiments at various temperatures indicates that relative survival of virus and coliform bacteria differs ac-

cording to the virus type and the exposure temperature. Neither phage nor coliforms are resistant to either temperature extreme, -55° or 99°C. At 20°-30°C. and at 36°-38°C. coliforms not only survive but multiply for a period of time, whereas virus may survive, but at a decreasing rate. Phage exhibits greater survival — i.e., more resistance — than *Bact. coli* at 60°C. temperature and at 8°-10°C., yet Theiler virus survival at 60°C. is negligible.

Chlorination

Fifty- and 250-ml. amounts of autoclaved spring water, inoculated with 10^4 cells of *Bact. coli* 3635, with 10^3 to 10^5 particles of *Bact. coli* B phage, or Theiler (5 M.E.D. M.E.D. = 6.3) or Coxsackie (70 M.E.D. M.E.D. = 8.2) virus were dosed with from 0.1 to 10 p.p.m. chlorine at room temperature. At the end of 10 minutes the residual chlorine was determined (12d) on approximately 45 ml. of the suspensions, and the numbers of surviving organisms determined in 4-ml. aliquots to which 1 ml. 0.01 N sodium thiosulfate had been added to stop the action of the chlorine. As indicated in Figure 6, survival of

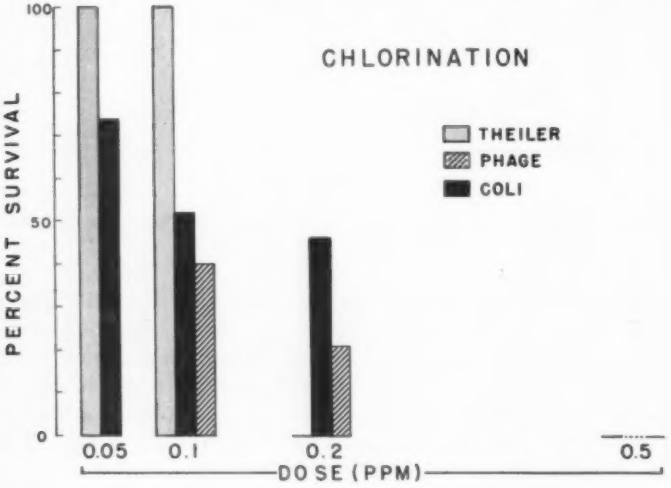

FIG. 6.—RELATIVE SURVIVAL OF COLIFORM BACTERIA, BACTERIOPHAGE, AND THEILER VIRUS IN WATER AFTER CHLORINATION.

phage and coliforms was approximately the same in the various doses given. A dose of 0.20 p.p.m., with a total chlorine residual of 0.03 p.p.m. and a chlorine demand of 0.17 p.p.m., for example, reduced survival of both phage and coliforms and destroyed Theiler virus completely. A dose of 0.5 p.p.m., with a total chlorine residual of 0.2 p.p.m. and a chlorine demand of 0.3 p.p.m., was sufficient to destroy coliforms and phage as well as the animal viruses. A low dose of 0.1 p.p.m., which reduced phage and coliform numbers considerably, had little effect, however, on Theiler or Coxsackie virus infectivity (Table 4).

The experiments with phage and coliform bacteria were repeated in autoclaved sewage, using chlorine doses of 1 to 50 p.p.m. The survival pattern was similar to that in water — i.e., both organism types survived at approximately the same rate in the various doses. Phage appeared to resist chlorination in sewage to a greater extent than *Bact. coli*, however, since it persisted longer; coliforms, for example, were completely destroyed at a dose of 10 p.p.m. while a dose of 50 p.p.m. was required to destroy lingering amounts of phage.

Sewage Treatment

This greater persistence of phage over coliform bacteria exists also in various stages of sewage treatment. When aliquots of sewage from the primary settling-tank effluent, trickling-filter effluent, and plant effluent of the Colonie sewage treatment plant were titrated for their natural coliform and *Bact. coli* B phage content in comparison to the numbers found in the raw sewage influent, the per cent survival of phage was greater than that of coliforms in all stages examined (Figure 7). While sedimentation and filtration may have lessened the amount of Coxsackie viruses, effluents from these steps in sewage treatment contained detectable amounts of these viruses.

Ultraviolet Irradiation

Since ultraviolet irradiation has been used under certain conditions for water treatment (14), its relative effectiveness on coliform and bacteriophage survival was examined. Several types of ultraviolet irradiation were used: direct sunlight, ultraviolet water sterilizer, Habel-Sockrider apparatus, and Westinghouse and General Electric Sterilamps.

TABLE 4.—SURVIVAL OF COLIFORM BACTERIA, *Bact. coli* B BACTERIOPHAGE, THEILER AND COXSACKIE VIRUSES IN WATER AFTER CHLORINATION

Chlorine dose (p.p.m.)	Residual chlorine (p.p.m.)			Chlorine demand (p.p.m.)	Per cent survival			
	Free	Combined	Total		Coliform bacteria	Bacterio-phage	Theiler virus	Coxsackie virus
0.05	0	0	0	0.05	74	9	100	0
0.1	0	0.01-0.03	0.01-0.03	0.07-0.09	0.06	0	100	
	0	0.02	0.02	0.08	99	87		
	0	0.01	0.01	0.09	60	65		
	0	0.03-0.04	0.03-0.04	0.06-0.07	100	0.02		
	0	0.02	0.02	0.08	0	0.01		50
	0	0.00	0.00	0.1		84		
0.2	0-0.01	0.03	0.03-0.04	0.16-0.17	66	58		
	0	0.02-0.03	0.02-0.03	0.17-0.18	0	0	0	
	0	0.03-0.05	0.03-0.05	0.15-0.17	72	6		
0.25	0.01	0.05	0.06	0.19	28			
	0.02	0.05-0.07	0.07-0.09	0.16-0.18	7	0		
0.3	0.01	0.04-0.05	0.05-0.06	0.24-0.25	50			
0.4	0.01	0.06	0.07	0.33		33		
	0.01	0.07-0.1	0.08-0.11	0.29-0.32	0.003	0		
0.5	0.03	0.15	0.18	0.32	0			
	0.03-0.11	0.11-0.18	0.21-0.22	0.28-0.29	0	0		
	0.02-0.03	0.10-0.12	0.12-0.15	0.35-0.38	0	0		
	0.01-0.03	0.12-0.15	0.15-0.18	0.32-0.35	0.03	0	0	
	0.01	0.09	0.10	0.4		0.002		
	0.07-0.18	0.10-0.30	0.19-0.48	0.02-0.32	0.01	0		0
1.0	0.05	0.15	0.2	0.8		0		
	0.1	0.2	0.3	0.7		0		
	0.23	0.18	0.4	0.6	0	0		
	0.2	0.1	0.3	0.7	0			
5.0	4.0	0.5	4.5	0.5		0		
	1.0	1.0	2.0	3.0		0		
10.0	4.5	3.5	8.0	2		0		

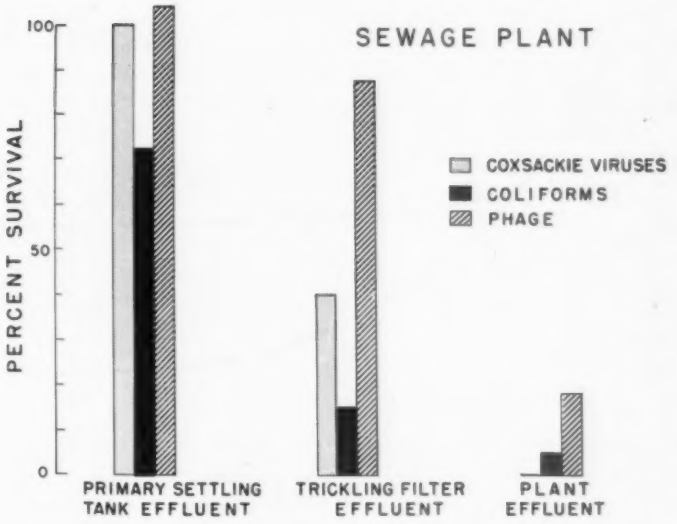

FIG. 7.—RELATIVE SURVIVAL OF NATURALLY-OCCURRING COLIFORM BACTERIA, *Bact. coli* B BACTERIOPHAGE, AND COXSACKIE VIRUSES DURING SEWAGE TREATMENT.

Direct sunlight: (1) Autoclaved spring water, containing approximately 10^4 cells per ml. *Bact. coli* 3635 or 10^3 and 10^5 particles per ml. *Bact. coli* B bacteriophage, was distributed as 10 ml. in Petri plates and exposed to direct noon sunlight. As indicated in Figure 8, coli and phage survived at the same rate except at the longest exposure given, which inactivated phage.

(2) Autoclaved sewage, containing 10^4 cells per ml. *Bact. coli* 3635 or 10^3 and 10^4 particles per ml. *Bact. coli* B bacteriophage, was distributed as above and exposed similarly to sunlight. Coliform bacteria were hardly, if at all, affected by the exposure, whereas the survival rate of bacteriophage was considerably lowered.

Ultraviolet water sterilizer: Fifty-gallon quantities of Albany tap water were inoculated with *Bact. coli* 3635, M.P.N. per 100 ml. of 3,300-7,900, or with *Bact. coli* B bacteriophage, 835-24,200 particles per ml., and were passed through an Elenite water sterilizer contain-

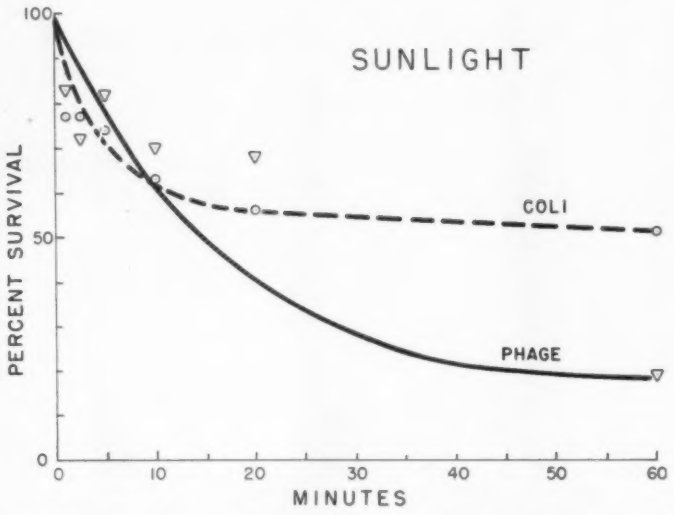

FIG. 8.—RELATIVE SURVIVAL OF *Bact. coli* 3635 AND *Bact. coli* B BACTERIOPHAGE IN SUNLIGHT.

ing six 30-watt ultraviolet lamps, at a rate to give an exposure time of 4.2 seconds. One-hundred-ml. samples were removed for survival counts. Coli survival in the sterilizer varied from 3 to 15 per cent; phage survival under this treatment was nil.

Habel-Sockrider apparatus: Although designed for antigen preparation, the Habel-Sockrider apparatus (15) could be used for small-scale water treatment. A modification of the apparatus was equipped with a General Electric Sterilamp, G36 T6. Two-hundred-ml. quantities of autoclaved spring water, containing 10^2 to 10^6 cells per ml. *Bact. coli* 3635, or 10^3 to 10^6 particles per ml. *Bact. coli* B bacteriophage, were passed through the apparatus at a rate that gave an exposure time of 15 seconds. Neither organism type survived ultraviolet irradiation in this manner.

Sterilamps: Autoclaved spring water, containing 10^4 cells per ml. *Bact. coli* 3635, 10^2 to 10^4 particles per ml. *Bact. coli* B bacteriophage, or Coxsackie (70 M.E.D. M.E.D. = 8.2) or Theiler (5 M.E.D.

M.E.D. = 6.3) virus, was distributed as 10 ml. in Petri plates and exposed to a Westinghouse Sterilamp WL 793 mounted 6½ inches above the suspensions and also to a General Electric Sterilamp G36 T6 mounted 9 feet 2 inches above the suspensions. Irradiation proceeded for periods of time up to 19 hours.

TABLE 5.—RELATIVE SURVIVAL OF *Bact. coli* 3635, *Bact. coli* B BACTERIOPHAGE, THEILER VIRUS AND COXSACKIE VIRUS IN WATER AFTER ULTRAVIOLET IRRADIATION BY STERILAMP

Exposure period (minutes)	Per cent survival			
	Coliform bacteria	Bacterio-phage	Theiler virus	Coxsackie virus
1	106	28	100	50
2.5	100	6	50	
15	31	0.3	0	0

As indicated in Table 5, phage was destroyed by irradiation periods of 5 minutes, whereas 4 hours or more were required for coliform bacteria. Coxsackie and Theiler viruses, while destroyed by irradiation periods of 10 or 15 minutes, as was phage but not coliforms, were more resistant than phage to short exposure periods—i.e., 1 and 2.5 minutes.

The experiments with phage and coliforms were repeated in autoclaved sewage. Coliform survival was greater than that of phage at the shorter irradiation periods, up to 5 minutes; beyond 5 minutes, the survival of both types was similar.

DISCUSSION

The significance of the coliform index as a measure of the sewage pollution of water has been firmly established. As an indicator of the effectiveness of water treatment it also has value. The data obtained in this study indicate that the relative survival of coliform bacteria and viruses in water is roughly the same. Under extreme conditions of temperature, however, there is a difference in the rates of survival. Under extremely low storage temperatures, there is a tendency for the intestinal viruses to survive for much longer periods than do coliform bacteria. At temperatures which roughly approximate seasonal variation in water storage temperatures, the coliform bacteria at times

survived for longer periods and at other times the intestinal viruses had the greater survival. These differences are minor and it may be concluded that the two rates of survival are comparable. In general, these differences in survival rates under varying environmental conditions are similar to the corresponding rates, reported by earlier investigators, for coliform microörganisms and the pathogenic bacteria which are incitants of intestinal disease. Since it is safe to assume that, like pathogenic intestinal bacteria, intestinal viruses would not be present in water except when accompanied by coliform bacteria, it may then be concluded that the absence of coliform bacteria, based upon the results of this study, will indicate the absence of intestinal viruses in sufficient concentrations to prove infective to test animals. It is interesting to note that apparently the use of *Bact. coli* B bacteriophage is not a significant means of measuring typical virus survival, since under some conditions, particularly as shown at temperatures of 60° C., there was a tendency for the bacteriophage to survive longer than the coliform bacteria and longer than the intestinal viruses investigated.

The failure of phage to survive at —55° C. seems contrary to the common practice of maintaining virus stocks at this temperature. Such virus stocks, however, are usually in the form of concentrated tissue suspensions and suspensions in broth that might exert a protective action. Also, measurements of viability of these viruses are frequently based on animal infectivity tests, which measure disease-producing properties, rather than on the quantitative methods applicable to bacteriophage determination such as plaque counting.

Lack of coliform survival in salt water may indeed be attributed to salinity. Hein de Balsac et al (16), however, suggest that the bactericidal properties of the sea waters around France may be due to antibiotic rather than to bacteriophagic or saline effects of the water. The apparent toxicity of river water for coliforms is of interest since Clarke (17) reports virus-inhibiting properties of Ohio River water.

One of the problems in the bacteriologic examination of water is the significance of the coliform group in indicating the safety of waters for bathing, particularly in indoor swimming pools where recirculation and disinfection treatment is practiced. Since indoor pools are maintained at warm temperatures and since bathing in natural water is generally restricted to seasons when water temperatures are at their

maximum, it would appear from this study that the destruction of intestinal viruses parallels destruction of coliform bacteria under comparable conditions of time of exposure to treatment. Thus, the absence of coliform bacteria may still be considered a measure of adequate treatment of pool water.

Because of the possibility that viruses, when discharged into water, may not succumb to residual concentrations of chlorine as rapidly as coliform bacteria, the chance of infection by contact with the water immediately after contamination has not been shown to be eliminated by the usual methods of treatment. From the results of the study, however, it is apparent that viruses as well as coliform bacteria are destroyed and consequently that chlorination in amounts sufficient to reduce coliform bacteria to insignificant densities would be accompanied by paralleled destruction of intestinal viruses. It is interesting that apparently the intestinal viruses studied are more susceptible to ultraviolet light disinfection than are coliform bacteria and if later tests continue to indicate this greater efficiency of ultraviolet light, its potential usefulness for disinfection of bathing waters would be considerable.

Studies are also needed for demonstrating the significance of predatory organisms which might aid in the reduction of viruses in a manner comparable to that which reduces the numbers of coliform bacteria in polluted natural waters prior to treatment.

On the basis of the data available, the coliform index may still be considered a reliable indicator of pollution of waters and their suitability for recreational and other uses, whether the pollution is of bacterial or viral origin.

Summary

Survival studies of coliform microörganisms in water and sewage in comparison with *Bact. coli* B bacteriophage, Coxsackie virus, and Theiler virus, indicate that their relative survival depends upon the type of treatment involved. During long-term storage in the cold, the viruses outlast the bacteria; at room or incubator temperatures, coliform bacteria grow. At the extremes of temperature, —55° C. and 100° C., neither phage nor coliform bacteria survive. At 60° C., on the other hand, the animal viruses are destroyed, along with coliforms, and it is phage which is most resistant.

Chlorination at strong doses (0.2 p.p.m. or more) affects the viruses and coliforms similarly. At weak doses (0.1 p.p.m.), however, animal viruses survive to a greater extent than phage and coliforms.

Ultraviolet irradiation destroys viruses to a greater extent than it does coliforms. At short exposure periods, 1 and 2.5 minutes, animal viruses survive to a greater extent than phage.

While phage is a convenient virus to handle, these survival studies suggest that it can be used as a type virus for predicting animal virus behavior only under known circumstances.

With the exceptions of storage in the cold and weak chlorine doses, water treatment which destroys coliform bacteria can be counted on to destroy viruses as well.

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BELIEVE-IT-OR-NOT EXPERIENCES WITH CHEMICAL FEEDERS

BY R. J. LEVEQUE*

[*Read November 19, 1953.*]

1.

The first "believe-it-or-not" experience happened in a rather large metropolitan city. They had installed one of our loss-in-weight type Gravimetric Feeders underneath a large storage bin. The feeder hopper was filled periodically by opening a bin gate between the overhead storage bin and the feeder hopper. In such cases, we always put a 4″-diameter vent on top of the feeder hopper, so that the displaced air can be exhausted. Our drawings showed a 4″-diameter duct, connected to this sleeve and running up through the floor above into the storage bin. This connection was to be made by the purchaser. The floor above, however, happened to be a very thick one, with quite a bit of steel reinforcement in it, and the maintenance crew at this plant, making the installation, apparently thought that there was an easier way to vent the feeder hopper.

They installed an elbow on the sleeve and ran the exhaust duct down into the feeder dissolving chamber, on the assumption that this would be a good way to get rid of the dust by exhausting it down into the water in the dissolving chamber. Soon after the installation was made, we received a call telling us that, for some unknown reason, there seemed to be considerable splashing of water in the dissolving chamber, which came up onto the feeding mechanism and caused an unsightly caking of the chemical on the interior of the feeder housing. At some time or other, I expect that many of us are apt to forget elementary principles. In this case, a thoroughly competent maintenance crew overlooked the fact that this displaced air would seek the highest point in which to exhaust itself. Our serviceman took one look at that elbow and right away surmised that air was collecting at

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that point and building up a pressure which, when it became great enough, exploded and blew downward with enough force to cause splashing of the water. When we called this to the superintendent's attention, he laughed rather sheepishly and admitted that the joke was on him. To keep him from having to run a long extension of dust duct up through the thick and heavily reinforced floor, we removed the elbow and attached a spring-suspended, cloth filter bag, such as are used in our dust-collector units. The next time the feeder hopper was filled from the storage bin, the displaced air and dust blew straight upward into the bag. The airfiltered out through the bag, while the dust was retained and dropped back into the hopper when the loading procedure was finished.

2.

While we are on the subject of air troubles, I should like to tell you of another experience that happened in a midwestern city.

They had bought an alum and lime feeder and, although our drawing had shown an open T on the discharge line just outside of the dissolver, they had connected a 1-½″ discharge hose directly to the dissolver outlet. There was only about a 4-foot drop to the point of application, but the end of the hose was submerged below the water level. A few days after they put the feeder into operation, they called for a serviceman and stated that the alum was apparently clogging up the hose. Frankly, we did not see how this could be possible but got on the job quickly. After watching the machine operate for a short period of time, it seemed quite obvious that there was air binding in the discharge line.

We mentioned this to the superintendent, but he was thoroughly convinced in his own mind that this could not be the problem. He said he could not understand how it was possible for a few bubbles of air to resist the 4-foot head from the dissolver. After assuring him that if our remedy did not solve the problem, we should give him a new piece of hose, he allowed our man to take a pocket knife and make a hole about ¼″ in diameter in the top of the hose, just where it connected to the dissolver. As soon as the hose was punctured, there was a slight gush of air and from then on the solution began to flow readily out of the dissolver.

3.

The next experience involves a Fluoridizer installation in a southern city, which was engineered to operate by proportional control. Specifications called for the flow to be measured through a 14″ orifice plate, signals to be electrically transmitted through a Chronoflo Transmitter and Chart Recorder. After they had made the installation, they wrote us saying that there was a marked discrepancy between the readings on the Builders Chronoflo Meter and their existing master meter. They mentioned that the Chronoflo readings followed the master meter readings up to and including 3 mgd. Beyond that point, they informed us that our Chronoflo read as much as 1 mgd lower than the master meter. Since it is sometimes difficult to diagnose troubles when the patient is 600 miles away from the doctor, we sent a man down to investigate. He found, upon his arrival and much to his surprise, that instead of installing the orifice plate to measure the flow, they had made a last-minute decision to tap onto the existing Venturi tube on their main discharge line from the plant. The maximum range through that 14″ x 8″ tube with their master meter was 0.291 to 5.82 mgd. Our original proposal, based on their using an orifice plate, covered the furnishing of a Builders Chronoflo with a measuring range of 0.82 to 8.2 mgd, utilizing 240″ of water.

It did not take long to point out that the discrepancy was due to the fact that calibrations on our meter were made on the basis of their using an orifice plate. As soon as we pointed out the reason for the discrepancy, they immediately agreed to the small additional expenditure necessary to provide change parts and a new range tube, calibrated for the differential on their Venturi tube.

4.

These experiences are not entirely without their humorous side and the following is an example. A city in Ohio has several of our Gravimetric Feeders, one of which is equipped with a rubber-bladed rotor, to prevent flooding of the material through the mechanism. We received a call from the operator, saying that the rotor mechanism was not operating properly and that material was flooding through. We suspected that something had become lodged in the feeding throat,

which was probably bending the rotor blades and breaking the seal, which permitted material to flood on through. We instructed him to remove the rotor mechanism after he had run his hopper empty, inspect it, and then report back the symptoms so that we might advise him what remedy was needed. We were, of course, prepared to send a serviceman if he could not solve the problem. Two days later, we received a letter from this superintendent, part of which read as follows:

> "I have just made a very interesting observation and have come to the conclusion that your feeders positively will not feed broom handles."

What had happened was that, in filling the hopper, one of the operators had used a long pole to level up the material in the hopper and it got away from him. For reasons best known to himself, probably fear, he did not report the incident and his negligence resulted in some chewed up rotor blades.

5.

To continue in a humorous vain, someone once asked an equipment manufacturer why they couldn't build equipment that was foolproof. The manufacturer replied, "It just can't be done because fools are too ingenious." That quip, of course, is not intended to reflect in any way on the integrity or ability of water-plant operators. But since this is a "believe-it-or-not" narration of experiences, I am sorry to have to report that at times there are operators who seemingly are not as conscientious or trustworthy as they should be.

The following experience happened in a water treatment plant of a large industrial concern. They reported that one of our belt feeders was not feeding accurately. We sent one of our best men down to check over the installation. He observed the feeder in operation, and the scale beam seemed to be sensitive enough and apparently acting under normal conditions. Gravimetric Feeders are so constructed that if for any reason chemical feeding becomes erratic or inaccurate, the scale beam will immediately go out of balance and an alarm bell will ring to warn the operator. Our expert spent quite a bit of time observing that feeder in operation and frankly he was baffled, because apparently nothing seemed to be wrong. He decided to make

another complete checkup before leaving and, quite by accident, when peering up into the feeder, he discovered that the scale beam had been cleverly tied with a very fine wire, which would permit it to oscillate, but not enough to go out of balance. You can imagine our surprise at the ingenuity of this operator. We could only assume that since he was an operator on the night shift, the ringing of the bell disturbed his sleep and he resented having to get up in the night to remedy the trouble or to fill the hopper. They say that lazy people always make the best inventors and you can take it from me that this guy really did a job on that scale beam. His work was a masterpiece of concealment.

P.S. "Willie doesn't work there any more."

6.

Our most baffling experience happened on a Gravimetric Feeder installation in New York State. The superintendent wrote us that the feeder would not operate properly and that the alarm rang continuously, no matter what they tried to do in the way of adjustment. He said the ringing of the alarm could not be stopped without shutting the feeder down.

We sent a man up there and he performed all of the usual close checks, but could find nothing wrong. The hopper was then filled with material and the feeder started. It ran continually until it had fed all but a pound and a half of the chemical. During this entire period, the machine functioned normally and the scale beam stayed in balance. The superintendent was exasperated. He surmised that the trouble was probably due to the fact that his six operators had six different versions of how this feeder should be run, but apparently they got so mixed up with their own method of trying to run it that not one of them could run it correctly for any length of time. The superintendent was satisfied after this demonstration that there was nothing wrong with the feeder. Our man told him, however, if further trouble was experienced, to call him personally and he would come again. Our serviceman, of course, felt confident that no further trouble would occur.

You can imagine his consternation when, two days later, we

received a telephone call from a very indignant superintendent, saying to "get up here at once or else." Our man got as far as New York by plane but couldn't get out of there because of weather conditions. He had to take a train, which delayed him almost a day. When our serviceman arrived, he found the feeder operating normally again. He was then more perplexed than ever and decided to take a walk around the plant to do a little deep thinking. His walk took him upstairs to the chemical-storage room and, being naturally curious, he inspected the dust discharge duct from our dust-collector unit, which extended to the outside of the building. This line was equipped with a damper and our serviceman started fiddling with this damper, to see if it was working freely. He left the damper open for about a minute, when, lo and behold, the bells on the feeder downstairs started ringing like mad. He said to himself, "No, this just can't be," but on the other hand, there it was. A rather strong wind was blowing outside in the direction of the dust duct. The velocity of the wind, blowing back through the dust duct, was great enough to upset the balance of the delicate scale mechanism and cause the alarm to sound. Upon calling this to the attention of the superintendent and operators, they seemed to recall that on those days when the feeder gave them trouble, the wind was blowing right sharply. They went back upstairs and closed the damper on the exhaust duct. The feeder scale beam went into balance shortly after and the bell stopped ringing. By way of a permanent remedy, it was suggested that the damper be removed from the exhaust duct and an elbow pointing downward be installed. We are happy to report that we have had no further complaints from this source.

7.

An Illinois plant superintendent reported to us that the chart recorders on our feeders presented damaging evidence against an operator who was not handling his job properly. It seems that this operator was scheduled to fill the feeder hopper every morning at 7 o'clock. He would lock the scale beam on the loss-in-weight Gravimetric Feeder to keep it steady while filling. After moving the balance poise out to the end of the 500-lb capacity scale beam, he would go upstairs and fill the hopper. As he knew the superintendent was not

in the habit of arriving at the plant until about 8 o'clock, at about ten minutes to eight, the operator would come downstairs, unlock the scale beam, and balance out the poise on the scale beam. The scale-beam capacity was 500 lb, but quite likely the operator had dumped in only about 437 lb. Although the rate of feed was set to deliver 37.5 lb per hour, or 25 lb in a 40-min period, 412 lb being left in the hopper, the operator had to balance his scale beam by moving the poise back to 412 lb. Since he had previously moved the poise out to the 500-lb mark on the scale beam, this showed up on the chart supposedly as the amount he had dumped into the hopper, to begin the shift's run. Subtracting 412 from 500 gave 88 lb as fed during this period, which the superintendent knew was erroneous. Since moving of the counter-poise registers a corresponding distance on the chart recorder, representing pounds fed, the error showed up glaringly and forced the operator to give an account of what he was doing between 7 o'clock in the morning and ten minutes to eight. All denials of philandering by that operator were of no avail. The superintendent, pointing to the chart recorder, quoted Omar Khayyam: "The Moving Finger writes; and having writ, moves on; nor all your Piety nor Wit shall lure it back to cancel half a Line, nor all your Tears wash out a Word of it."

8.

During the second World War, we received a hurry-up call from an ordnance plant in Iowa. They had made a beautiful installation of one of our feeders and slakers, which was being used to feed quicklime to soften the extremely hard water found in the gravel beds of central Iowa. Their trouble seemed to stem from the fact that every day or two their lime slaker clogged up, because of lime plating out on the sides of the slaker and on the impeller. The high-speed impellers, turning at about 800 rpm, caked up with some material so that they looked like large coconuts. The 1-3/16″-diameter tapered shafts on these mixers looked like baseball bats.

Inasmuch as we had never heard of any such thing's happening in our slakers, we had to go and see this phenomenon in order to believe it. Well, seeing was believing, sure enough. Upon examina-

tion we found a limestone coating, which was building out on the sides of the slaker, and the mixer shaft was actually "growing" in diameter. Naturally, we were perplexed. We had seen lime slakers operated for over a year at a time, without even stopping to clean them out, and when they were cleaned, the sides of the slaker below the water level were clear right down to the metal.

Our first check was to ascertain if they were keeping the temperature up, to insure efficient and complete slaking. Since we found the temperature high and well within the range to give efficient slaking, we assumed they were using about a 4- or 5-to-1 water-to-lime ratio, in order to obtain these high operating temperatures. Further investigation, however, revealed that this was not the case. They had a large supply of warm water available from a heat-exchanger process and they were simply diverting all of this water into the slaker. Instead of a 4-to-1 water-to-lime ratio, it developed that they were using about a 14-to-1 ratio.

As a result, softening action was apparently taking place in the slaker and the high velocities, caused by the high-speed mixers, caused the material to plate out. We brought this to their attention and they immediately reduced the water supply to the slaker to about a 6-to-1 water-to-chemical ratio. This plating-out disappeared entirely and from then on the slaker operated in a normal manner. The impellers and the sides of the slaker below the liquid level remained absolutely clean of deposits, and the small amount of lime that adhered to the slaker and impeller shafts above the water level, due to splashing, was chalk-like in composition and could be easily removed.

9.

While on the subject of slakers, an experience comes to mind at another plant, where the operators were afraid to operate the slaker at high temperatures. Throughout the years, we have stressed high-temperature slaking as being proper and more economical. We have consistently recommended that temperatures never be permitted to fall below 160° F. To prove that there is no danger in operating slakers at this temperature, our servicemen have gone into plants and started up slakers, frequently operating them at temperatures up to 190° and 200° F.

Nevertheless, in this plant, although the day shift operated slakers at about 150° to 160°, the night shift, wanting to play safe, opened up the water valve and let the temperatures drop to around 100° to 110°. Operating at these extremely low temperatures resulted in considerable unslaked lime's leaving the slaker. On one occasion, this unslaked lime gradually built up in a 6″ discharge line, so that finally the discharge line (which was built large to avoid stoppage) completely filled up and the slaker started to overflow. The operator, noting the difficulty, picked up a piece of ½″ reinforcing bar, which had previously been used to rod out the discharge line, whenever it showed signs of plugging up. This time, however, the moment he tapped the plug in the discharge line, it blew up in his face, causing severe burns.

What happened? Well, the large particles of unslaked lime had settled in the discharge pipe, continued to slake and, as they slaked, more heat was evolved, so that neighboring particles of lime, which only needed heat to make them slake properly, also started to slake. When all the available water in the pipe was used up, steam began to form and the operator happened along just at a time when the pressure, built up in that pipe, was extremely great. The moment he made a hole in the plug of lime, the steam rushed upward like a geyser.

Things are not always what they seem and, in this case, operating at low temperatures was not the safe thing to do. As a matter of fact, the opposite of safety resulted, causing a dangerous condition, resulting in a serious and painful accident.

10.

Back about 1930, a private water company purchased one of our early-model Universal Feeders for ferrous sulphate. At that time, they were slaking by hand. Later they purchased several continuous lime slakers from us and are still using them.

Chemicals are hauled from a freight siding some distance away by truck into the plant. At that time, they used an inclined screw conveyor to elevate quicklime and ferrous sulphate (copperas) into overhead storage bins. The same screw was used for both chemicals and proper gates opened to allow the right chemical to go into the

right bin. A small leak developed at one of the connections to the screw, so that a thin stream of chemical sifted down onto a boardwalk below the conveyor during the loading operation.

In one instance, both copperas and quicklime were loaded the same day. Near the end of the filling operation, one of the employees noticed that the boards below the conveyor were burning away merrily.

What had happened was this. The lime had absorbed some of the water of crystallization in the copperas, causing it to slake. As it slaked, the temperature rose, increasing the speed of the reaction. Pretty soon, the small mass of mixed quicklime and ferrous sulphate reached combustion temperature and the boards broke into flames.

There have been similar instances of fire starting or of filter bags in vacuum-type unloading systems becoming charred, where the same system is used for ferrous sulphate and quicklime.

In just a recent instance, the same conveyor system was used to elevate alum and quicklime to steel storage bins. The alum bin and the quicklime bin were adjacent and the operator manipulated proper valves in order to direct the quicklime into the quicklime bin and the alum into the alum bin. With such installations, it is inevitable that mistakes are bound to occur. As a matter of fact, in this case, our engineers warned them that this would happen. In the interests of economy, however, they decided that a single elevator would have to be used.

Within the first two or three months, the inevitable happened. Alum was dumped into the quicklime bin. Pretty soon the bin began to heat up. Paint began to smoke and peel off of the steel bin and the fire department was called. They very wisely decided against putting water into the bin, which could very well have caused the quicklime to explode. Outside of learning that it was an awful mess and that the final "melt" had to be dug out of the bin by men with picks and axes, we did not learn any further details. Presumably the firemen played water on the outside of the bin, to keep the temperature down as much as possible, to prevent the bin and steel supporting members from buckling.

A few years later, when this city built an additional filter plant, they used separate elevators for each chemical.

11.

In conclusion, I should like to relate an experience that happened in a large industrial-waste treatment plant in Michigan. The equipment had already been installed by the contractor and merely had to be checked and given a final inspection by the servicemen of the various equipment manufacturers.

The superintendent of the plant had confidently set a date for starting up, with the hope that all they would have to do would be to go around and push buttons and the plant would merrily start to function. Our equipment consisted of several chemical feeders and a couple of lime slakers, so that probably a dozen motors were involved insofar as our equipment was concerned. Our serviceman arrived early in the morning and, when he started up our machines, he found four motors running backwards. Actually, this represented 33-1/3% of the motors on our equipment, turning in the wrong direction, and to him this seemed a rather high percentage. After reversing the leads on these four motors, to make them run properly, he decided to take a walk around the plant while awaiting the time for the plant to be put into operation. The first thing he noticed was a centrifugal pump that was not behaving properly. He called the superintendent's attention to the pump and said he believed it was running backward. Sure enough, it was.

Together they walked over and observed an exhaust fan, which was being tried out. They noticed that it also was running backward. Right then and there, the superintendent decided he would postpone starting the plant for another day, so that he could make a complete inspection of all motors. "Believe it or not," in this plant they found a total of 29 motors turning in the wrong direction.

In summing up these experiences, it would seem that truth after all is stranger than fiction. And, if these incidents I have related have any moral at all, I believe you will agree that it is that servicemen sent out by equipment manufacturers can be most helpful, not only because of their familiarity with the specific equipment involved of their own manufacture, but because of their background, general knowlege and experience gained from the sort of situations outlined in this talk; they are quite often in a position to render assistance in getting the bugs out of new plants and getting them into operation in a hurry.

IMPROVEMENTS TO THE KITTERY WATER DISTRICT

BY FRANCIS L. HATCH*

[*Read December 17, 1953.*]

A brief sketch of the history of the Kittery Water District seems necessary, in order that the growth and improvements to this small water system may be appreciated.

In 1904 the Agamenticus Water Co. built dams at Middle and Folly Ponds in York, Maine; ran a 12-inch main from Middle Pond to York River; connected it to three 8-inch mains, which were laid on the river bottom on piling, and then connected to a 12-inch main, which was extended through York into Kittery and the Portsmouth Navy Yard. This original main was intended to supply the Navy Yard only, but a few people were allowed to tap it.

Through the efforts of Hon. Horace Mitchell, an act to incorporate the Kittery Water District was passed by the State Legislature and signed March 20, 1907. On April 8, 1907, the citizens of the District voted to adopt the Charter and on April 9, 1907, Trustees were elected.

After the Charter was granted, the first step taken by the Trustees was to open negotiations with the Agamenticus Water Co. for the purchase of their plant. Since no agreement on purchase price could be reached, the matter was referred to the Supreme Court of York County. The case was tried by a Commission appointed by the Court. The Commission recommended an award of $163,869.38 to the Agamenticus Water Co. and costs of $2,004.00 to be borne by both parties. The final decree confirming the Commission's report was handed down by the Court February 1, 1908.

In order to raise funds to pay for plant and make extensions, bonds were issued to the amount of $210,000. During the year a main was laid to Kittery Point and through principal streets in Kittery village. Extensions were made thereafter as revenue would allow.

* Superintendent, Kittery Water District, Kittery, Me.

In 1913 the Trustees voted to extend the line into the town of Eliot and notes for $35,000 were issued to cover cost of extensions. In 1914 a six-inch main was laid over Tenney Hill, Cutts Island Lane, and Chauncey Creek Road, Kittery Point, at a cost of $15,000.

In 1918, due to the insistence of the Government on a larger supply of water, $200,000 worth of bonds was issued, to cover the cost of installing new 14- and 12-inch mains from Middle Pond, York, to Kittery and raising Middle Pond dam 6 ft and Folly Pond dam 4 ft. This new 14-inch and 12-inch main ran parallel to existing main part of the way. At York River both mains were connected to a new 16-inch main, which was laid on a trestle over the river and along Scotland Bridge Road to Beech Ridge, a distance of 6,000 ft. This was connected to an old 12-inch main and new 12-inch main which was extended into Kittery. The old river crossing of three 8-inch mains was then salvaged.

In 1934 a new steel bridge, resting on granite piers, was built over York River. A 16-inch and 12-inch main was laid on the bridge; both mains were connected to existing 16-inch on each shore. The cost of new bridge and demolition of old trestle was $19,807.46

A 500,000-gal standpipe was built in Eliot in 1936. This greatly improved service there and helped maintain more constant pressure in Kittery. The cost of standpipe, land and pipeline was $20,850.82.

The war-time activities of the Portsmouth Navy Yard, situated in Kittery, Me., together with a 600-family-unit, Federal housing development, known as Admiralty Village, placed a greatly increased demand on the facilities of the District. As a result of this, it was decided to build another dam, about 500 ft farther upstream than the existing dam at Folly Pond and at a higher elevation, to increase materially the storage capacity of the reservoir. The gravity section of the new dam is built of concrete and is about 21 ft high and 150 ft long; the remainder of the dam is constructed of earth and stone with a concrete core-wall. The ledge seams under the dam and core-wall were grouted under pressure with cement. This dam, constructed 7 ft higher than the elevation of the old structure, allows additional storage of about 200 mil gal of water. It was also necessary to build an earth dike about 640 ft long at the north end of the reservoir, to prevent the water from running onto another watershed.

The dam and dikes were built between the winter of 1941 and the spring of 1942 by John MacDonald Construction Co., of Newton, Mass., at a cost of $84,287.56.

By March, 1942, the water in Folly and Middle Ponds, the two reservoirs then making up the water supply of the Kittery Water District, was at a low level and an additional supply was sought. Under these pressing conditions the District sought funds from the Federal Works Agency under the Lanham Act and a $60,000 grant was made available at once. Plans and specifications were prepared within a week and a contract was awarded by the Federal Works Agency to Edward M. Matz, Inc., for building a pumping station on the shores of Chase's Pond, with two 12-inch cast-iron intake pipes installed on piling driven through the ice in Chase's Pond, and for a 12-inch cast-iron pipeline laid on the surface of the ground to Folly Pond, a distance of 2,840 ft. The terrain was very rough and the pipe was in general, laid cribbed into place by timber and rock foundations and the bell-and-spigot joints were made tight with Leadite.

The site of the Chase's Pond pumping station is about a mile from a gravel surfaced road. The pipe, equipment, and building materials were carted to the site with tractors and wooden sleds, due to the rough terrain and thawing ground. The sleds had about 8-inch wooden runners, which had to be replaced each day after making two trips.

A contract was awarded at the same time to Ralph P. Hall, Inc., to furnish and install in the pumping station at Chase's Pond two diesel-engine-driven pumping units. One centrifugal pump has a capacity of 1,400 gpm and is belt-driven by a 75-hp Caterpillar engine. The other centrifugal pump has a capacity of 700 gpm and is belt-driven by a 38-hp Caterpillar diesel engine. The pumps are primed by means of gasoline-engine-operated Nash vacuum pumps. The installation has a total capacity of 3 mgd.

In 1932 the Kittery Water District built a chlorinating plant, located in the wilderness of York near Folly Pond, at a point where two 12-inch mains, conveying water from the reservoirs to Kittery, are laid close together. At this location the flow from both pipelines is passed through a single Venturi meter, 16″ x 8″. The flow is measured by a Builders recorder. The water at this location was

treated with chlorine and ammonia by means of Wallace & Tiernan equipment. The equipment is so arranged as to vary automatically the application of chlorine and ammonia directly as the flow varies. Later an addition was made to the chlorine plant and new automatic chlorinating equipment was installed.

As stated above, there are, in general, two 12-inch water mains extending about 8 miles from the reservoirs to Kittery proper. However, there was a gap where only one 16-inch main existed, and 6,000 ft of 12-inch pipe were laid to fill in this gap, which occurred in the town of York along Scotland Bridge Road, from the corner of South Berwick Road to Beech Ridge Road. This water main crossed the York River, the crossing having been built at a previous date. This water line was constructed of bell-and-spigot 12-inch cast-iron pipe with Leadite joints. This work was likewise done by John MacDonald Construction Co. Other water-main extensions were made at many locations, to meet the war housing and government agencies' requirements, at a cost of $78,673.

As the water consumption continued increasing, it became evident that it would be necessary to have more water available in York, Kittery, and Eliot, which are served by the Kittery Water District. At times of heavy draft, the water pressure was inadequate. A contract was awarded to Layne-Bowler New England Co., to drive test wells in an effort to locate a satisfactory ground-water supply. Many test wells were driven throughout Kittery in the winter of 1942 and 1943 without success.

A spring, known as Cottle's Spring in Eliot, situated about 2,000 ft from the Eliot standpipe, was located and developed by this writer. The water is of excellent quality and is slightly chlorinated. This spring delivered 140 gpm. A temporary gasoline-engine-driven pump was set up, with 1,400 ft of 4-inch pipe laid over the surface of the ground, to connect it with the distribution main. Later, an electric-motor-driven pump, having a capacity of 250 gpm, was installed and a 6-inch discharge main was laid underground. This water supply from Cottle's Spring has been of great assistance and meets about all the requirements of the Eliot section.

Late in the fall of 1943 it became evident that the water consumption was increasing to such an extent that the two pipelines

conveying the water from the reservoirs to Kittery would not have the necessary capacity to meet the demands of the following summer. Studies were made to increase the capacity of the existing pipelines. The hydraulic gradient along this pipeline having been observed at different times during the summer of 1943, a profile was plotted showing the earth's surface and the hydraulic gradients from the reservoir to Kittery proper. It then became necessary to locate a position along the pipeline where the pipes were spaced reasonably close together, and so located that the hydraulic gradient could be lowered between that location and the reservoir sufficiently to give a flow of about 2,000 gpm, and yet not lower it enough to take the water away from any buildings, and to provide sufficient pressure for fire protection at Cider Hill and Beech Ridge, York. It was also necessary that this booster pumping station be so located that the hydraulic gradient on the discharge side of the pump, when pumping 2,000 gpm would not be so great as to break the existing Class B, pit-cast pipe.

The location finally selected was on Cutts Road, about 3½ miles from Kittery Center and about 4½ miles from the reservoir. The studies made showed that the flow through the pipelines could be increased from about 1,250 gpm to 2,000 gpm by boosting the pressure at this location about 47 lb. Contracts were awarded to George E. Duteau for building the booster pumping station and outside pipe connections and to Ralph P. Hall, Inc., for installing the pumping equipment. A Gould centrifugal pump was installed, driven by a 125-hp motor. The electric controls are automatic—the pumping unit may be started and stopped by pressure or by time, as desired, or by a combination of both. The piping is so arranged by means of check valves that when the pump shuts down, the water continues to flow by gravity from the reservoir, as it did before the building of the pumping station.

One 4-inch relief valve and two 3-inch relief valves were installed at the pumping station on the discharge side of the pump and were set to discharge at various pressures slightly above the maximum working pressure, in order to snub effectively any surges that might occur in the line. These pressure-relief valves have worked very satisfactorily, as has the pumping station. Total cost of this station was $19,779.

For some years the Kittery Water District had experienced trouble with eels in its water system. During the summer of 1945 the situation became acute. However, an examination showed that breaks in the brick runways holding the screens at the screen chamber allowed eels to pass around the screens, and it was found that in order to rebuild the 35-foot-high brick runways, it would be necessary to divert the water around the dam while this work was going on. This would require installing a temporary screen on the by-pass pipeline and a considerable amount of difficult work, as the existing valves, installed when the dam was first built, could not be relied upon. If, during the course of the work, the temporary screen became clogged, Kittery would be without water. After considering the hazards involved, the difficulty in repairing the existing structure and the inaccessible location, it was decided to install new strainers in a building at a more readily accessible location. The site selected was immediately upstream from the existing chlorinator building.

Many types of strainers were considered and, after much study, it was decided to install four multi-duct strainers, each strainer containing three baskets, two of which are in operation at all times. The water supply is secured through two 12-inch pipes at the location of the strainer building and, in order to install four strainers, it was necessary to relocate these pipes and to branch off from each pipe with a 12-inch pipe. A gate was placed on each side of each strainer, so that it could be readily shut off in case of the need of repairs or the like. The strainer baskets are 12 in. in diameter and about 12 in. long and have 3/16-inch circular openings. The total area of the holes in each basket is about 1½ times the area of the 12-inch pipe, so that with two baskets in operation on each strainer at all times, the area of the holes in the strainers is equal to about three times the area of the 12-inch inlet pipe. No interruption of service occurs during cleaning, the construction being such that two baskets must be in service while the third is being cleaned. Pressure gauges are installed on each side of each strainer and if the drop in pressure through the strainer is 2 lb or more, the strainer is then cleaned.

Much consideration was given originally as to whether to put in 2 or 4 strainers. As there was no information available on such an installation, it was decided to be conservative and to install four;

experience has shown that to have been good judgment. However, if the strainers were to be installed in a pumping station or the like, where they would be frequently inspected, probably two strainers would be sufficient.

The entire plant cost about $16,373.17. The strainer building was constructed by C. L. Guild Construction Co.; strainers were manufactured by Blackburn-Smith Manufacturing Co., and the piping and equipment were installed by Ralph P. Hall, Inc.

In 1946 the masonry dam at Middle Pond was found to be in an unsafe condition, due to erosion. During the fall of 1946 and spring of 1947, C. L. Guild Co. repaired the face of the dam and also pumped tons of concrete into the voids, caused by erosion of nearly all of the mortar in parts of the dam. The cost of sealing off leaks and restoring safety factor of the dam was $21,737.14.

During August, 1949, due to the extended drought and heavy water consumption, the water level in the reservoirs was so low that they contained only about a month's supply. On August 15, the emergency diesel-engine-driven pumping station, built during March, 1942, as a war-time measure, was put into operation and 85 mil gal were pumped from Chase's Pond into Folly Pond up to November 23, 1949, when pumping ceased.

The future water-supply requirements of the Kittery Water District are very problematical, due to the fact that it supplies the Portsmouth Navy Yard, which is located in Kittery. The quantity of water used by the Navy Yard varies greatly from time to time. Based on studies made by Whitman & Howard, Engineers, and on data furnished by the Navy, it was estimated that in 1970 the average daily water consumption may be about 3.2 mgd and the maximum about 5 mgd.

The water supply, at that time, including Cottle's Spring, was believed to be capable of yielding continuously an average daily supply of 1.4 mil gal. Thus it may be seen that another supply which would yield about 1.8 mgd would be necessary, to meet the estimated 1970 requirements.

After considerable investigation, a site was selected on Bass Cove Creek and a dam built, with spillway 75 ft above mean sea level, which impounds 500 mil gal, with a water-surface area of about 105

acres and a watershed of about 2.3 sq mi. The dam is of earth-fill construction with concrete core-wall, and has a spillway at one end, cut through rock. The dam is about 930 ft in length and has a maximum height above the original earth surface of 41 ft. The concrete core-wall is 2 ft wide at the top and has a batter of 1 ft in 50 on both sides. The core-wall sets on ledge for its entire length and has a maximum height of 70 ft.

The ledge below the core-wall was grouted, to prevent or minimize leakage through seams in the ledge rock under the dam. The grout holes were drilled 12 in. on centers to a depth of 12 ft and filled with grout under pressure, consisting of one part Portland cement and one part sand. An average of ¾ cu ft of grout was pumped into each hole. At times the grout came out through holes drilled in the ledge 4 or 5 ft away. The pipes from the grout holes were extended up through the core-wall forms and through the side of the forms at a height of about 4 ft above the ledge. Grout was not placed until at least one 10-foot lift of the core-wall had been poured.

The concrete core-wall was placed in 10-foot lifts. The forms were continuous, with bulkheads located as required by a day's pour, depending on the weather, temperature, etc. The concrete was designed to have a minimum compressive strength of 2,500 psi. An air-entraining agent was used in the concrete which, together with mechanical vibrators, gave a dense, uniform concrete mass without voids in the concrete, and which prevented the water from rising to the surface and the formation of a laitance at the top surface of each pour.

The matter of construction and expansion joints was given serious consideration and it was concluded to build the dam without expansion joints. Five-eighths-inch steel reinforcing bars were placed in two directions, close to the surface of each side of the core-wall, in order to prevent the formation of large expansion and shrinkage cracks, due to changes in temperature, etc. This seems to have been successful, as only minute hair-line cracks were observed previous to filling about the core-wall. The construction joints, in both horizontal and vertical directions, were built with 4-inch-by-6-inch concrete keyways. Steel water stops were installed at each construction

joint of ¼-inch-by-12-inch steel plates, which were arc-welded at all joints.

A drainage system was constructed along the downstream face of the core-wall. This consisted of a 6-inch concrete pipe with 3-inch to 6-inch stone to a thickness of 4 ft placed around the pipe. The drains discharge into the old creek bed below the toe of the dam.

The spillway has a capacity of 2,500 cfs. This will take care of the maximum one-hour rainfall along the New England coast plus melting snow. The extra storage above the spillway will take care of a storm of twice the intensity of the record one-hour storm, thus giving a quite large factor of safety.

The intake tower is so arranged that water can be drawn into the intake tower through 16-inch-diameter intakes at three elevations. Sluice gates were placed on the two upper intakes and an ordinary gate valve on the lower intake. The sluice gates are used at the higher levels rather than gate valves, due to the danger of ice formation breaking the bonnets of gate valves.

Water flows from the reservoir to the pumping station through either or both of the 16-inch pipelines which extend through the dam, encased in a reinforced-concrete supporting structure. A blow-off is provided, to discharge into the old stream bed. The upper face of the earth fill of the dam is paved with stone rip-rap. The lower face is grassed.

The construction work was performed under a negotiated contract by Landers and Griffin, Inc., of Portsmouth, N. H. Due to the acuteness of the situation, actual construction was started within one week of the time that Whitman & Howard, Engineers, were instructed to undertake the work. Only preliminary plans had been developed when the construction work started. The plans were developed as the work continued, which required close coöperation between the engineers and contractors.

A pumping station was built at Boulter Dam. The pump discharges into a new 16-inch main, which was connected with existing 12-inch mains—one on each side of the new dam. This new 16-inch main was laid across country to Scotland Bridge Road, where it was connected to existing 16-inch and 12-inch mains which ran to Beech Ridge. From connections of 16-inch and 12-inch mains at Beech

Ridge, York, a new 16-inch main was laid across country to a booster station at Cutts Road, Kittery.

A new 16-inch main was connected to two 12-inch mains at Shepard's Hill, Kittery, and extended to a 12-inch main that enters the Navy Yard at Gate No. 2. It was also connected to a 10-inch main that supplies Kittery Point. The cost of land, dam, reservoir, pumping station and new mains was $656,624.87.

In 1951, 6,300 ft of 16-inch, 3,000 ft of 14-inch, 71,080 ft of 12-inch, 14,710 ft of 10-inch, and 16,000 ft of 6-inch main—a total of 111,720 ft—were cleaned by the National Water Main Cleaning Co., the total cost being $17,539.44.

Any remarks the author might make in regard to his experience in ridding the system of eels and cleaning mains would be unprintable.

To list all of the extensions and improvements since 1908 would be lengthy and boring. However, since February, 1908, the District has grown from 8 miles of 12-inch water mains, with its two small reservoirs valued at $163,869.38, to a system with 70 miles of mains, three reservoirs with a capacity of 1,060 mil gal, 3,317 customers, a daily consumption of 1,787,788 gal and total assets of $1,484,948.39, after deductions of $498,084.50 for depreciation, as of December 31, 1952.

Whitman & Howard, Engineers, drew the plans and supervised all of our major improvements since 1941. Ralph P. Hall, Inc., installed all our pumping equipment, chlorinators and strainers. The author is indeed fortunate to have had the privilege of working with the above-mentioned firms. It has been a great pleasure and an education for him.

In conclusion, a few facts about the Trustees of the Kittery Water District will reflect the confidence the citizens of the District have in our Trustees.

The first Trustees were elected April 8, 1907. At this time Hon. Horace Mitchell, Calvin P. Hayes and James H. Walker were elected, to serve for a 3-year term, a 2-year term, and a one-year term, respectively, and one Trustee was elected each year thereafter, to serve a 3-year term. All of the above-mentioned were reëlected as their terms expired and all died in office.

In 1914, George D. Boulter was elected to fill the vacancy left when Mr. Hayes passed away. In 1922, Mr. Boulter was elected President of the Board of Trustees. He has been reëlected each term and is still very active as President at 89 years of age.

Elmer J. Burnham was elected Trustee in 1922, to fill the vacancy left by the death of Hon. Horace Mitchell. Shortly after his election as Trustee Mr. Burnham was elected Treasurer and has been reëlected as each term expired.

Burnell E. Frisbee was elected Trustee and Secretary in 1941, to fill the vacancy caused by the death of James H. Walker. Mr. Frisbee has been reëlected as each of his terms expired.

Six Trustees in 46 years comprise a record that is hard to equal.

MEMOIR OF HAROLD K. BARROWS

Harold K. Barrows was born in Melrose, Mass., November 9, 1873, and lived as a boy in Reading. He was educated at the Reading High School and graduated from Massachusetts Institute of Technology in 1895. His first work was with the City Engineer in Newton and then with the Metropolitan Water Board in Boston until 1901, when he became for three years Assistant Professor of Civil Engineering at the University of Vermont. From 1904 to 1910 he was District Engineer for the United States Geological Survey in charge of their stream-gaging measurements, his district covering New England and New York.

In 1909 he was appointed Associate Professor of Hydraulic Engineering at M.I.T., where he gave courses in water-power engineering. He was made a full Professor in 1921 and served in that capacity for 20 years, becoming Emeritus in 1941. During this period a great many of the men who later became hydro-electric engineers took his course in the hydro-electric option.

In 1907 he also started his office as consulting engineer, specializing in hydraulic work—water power, water supply and flood control. From 1910 to 1930 Professor Charles B. Breed was associated with him in the firm of Barrows & Breed. His office at 6 Beacon Street, Boston, was retained until his retirement in 1950.

In 1927 he published the first edition of his book, "Water Power Engineering," which was very widely used by teachers and engineers all over the country. Three editions were published, the last one in 1943. In 1948 he published a book entitled "Floods, Their Hydrology and Control." He was the author of many papers in the publications of the American and Boston Societies of Civil Engineers and the New England Water Works Association.

Professor Barrows was a member, past president and honorary member of the Boston Society of Civil Engineers; a member and past president of the Northeastern Section of the American Society of Civil Engineers; a member of the American Institute of Consulting Engi-

neers and the New England Water Works Association (since 1902); an honorary member of the M.I.T. Chapter of Chi Epsilon, and a fellow of the American Academy of Arts and Sciences.

During his long practice of consulting engineering, he was engineer in various capacities for many state commissions in New England, New York and New Jersey. He took an important part in the special water-power investigation by the public utilities of the State of Maine, which was published in 1918. After the 1927 flood, he made flood investigations in Vermont for the state, the report on which was published in 1930, and during 1933-4, he made a similar study for the State of New Hampshire. He was regional consultant for the National Resources Commission from 1935 to 1938. For many years he served the State of Vermont as consultant in connection with approval of plans of dams built in that state. In Massachusetts he served the Metropolitan District Commission in connection with the appraisals of land damages in the development of the Ware River and Swift River water supplies. He served the State of New Jersey in connection with case of New Jersey vs. New York regarding the Delaware River. He was a member of the Board of Consulting Engineers of the T.V.A. for the valuation of surface water rights. He was also consultant for many municipalities and public utility and industrial companies on water-supply and water-power problems.

His professorship at M.I.T. and his large experience in state, municipal and private work throughout New England gave him a standing and reputation that was widespread throughout the whole community, with the result that his services and advice were required on all kinds of hydraulic problems.

In 1907 Professor Barrows married Mabel R. Jordan, who died in 1952. They had one son, Kilbrith Barrows, who survives him. Since 1907 they had lived in Winchester, Mass., where he died on March 15, 1954. He served as chairman of the Winchester Water and Sewer Board from 1913 to 1916. He attended the Unitarian Church. He was a former member of the Calumet Club, the Winchester Country Club and the Siaconnet Golf Club of Little Compton, R. I.

HOWARD M. TURNER

BOOK REVIEW

FRESH WATER FROM THE OCEAN. *By Cecil B. Ellis.* 217 pp. New York, N.Y.: The Ronald Press Co., 1954. $5.00.

In this book the author presents a report of a study, sponsored by The Conservation Foundation, of the problem of desalting sea water on a large scale and at a low cost. The book contains a systematic examination of the physical forces and techniques involved in separating salt ions from sea-water molecules. To determine the economic feasibility of large-scale production methods, all major cost elements are analyzed in terms of a capacity of 1,000 mgd, approximately the quantity used daily in the city of New York. In presenting the subject matter, the author has adopted a readable style rather than highly technical language.

The list of chapters is as follows:

1. The Problem.
2. Types of Separation Methods.
3. Energy Costs.
4. Long-Range Force Systems.
5. Actions on the Container.
6. Sieve Processes.
7. Distillation with Conventional Fuels.
8. Distillation by New Heat Sources.
9. Chemical Surface Methods.
10. The Sale of By-Product Chemicals.
11. A 1000-mgd Electric Membrane Plant.
12. Conclusions.

Appendix: Ideas for By-Passing the Problem.

The book contains a list of references after almost every chapter, as well as a 5-page index and 41 illustrations.

GEORGE C. HOUSER

RADIOLOGICAL HEALTH TRAINING PROGRAM

In recognition of the increased use of radiation and the associated health-protection problems, the Public Health Service, U. S. Department of Health, Education, and Welfare, sponsors a radiological health training program. The purpose of the program is to indoctrinate public health workers with the significance of ionizing radiations, the environmental and occupational hazards attendant on their use, and recommended procedures for minimizing such hazards. The training program is presented at the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. It is designed primarily for professional personnel of State and local health departments, but a limited number of qualified applicants from other governmental agencies and industry will be welcome.

The following courses are among those being presented in 1954-55. The readers of this JOURNAL might be particularly interested in them.

November 1-5 ....Problems of Radioactivity in Water Works
May 16-20 .....Problems of Radioactivity in Water Works
January 10-21 ....Basic Course in Radiological Health
April 18-29 .....Basic Course in Radiological Health
May 2-13 .....Environmental Radiation Sanitation

For further information address:

Chief, Radiological Health Training Section
Robert A. Taft Sanitary Engineering Center
4676 Columbia Parkway
Cincinnati 26, Ohio

PROCEEDINGS

April 1954 Meeting

Rhode Island Country Club, Barrington, R. I.

Thursday, April 15, 1954

Over 160 members of the New England Water Works Association and their guests gathered at Bristol, R. I., to tour and inspect the facilities of the Bristol County Water Co. in Bristol, Warren and Barrington. The tour included the newly remodeled and equipped office building in Bristol, the Warren Station (rapid-sand filtration plant and pumping station) and the Barrington Station (iron-removal plant and pumping station).

After luncheon at the Rhode Island Country Club, President William B. Duffy opened the meeting, introduced those at the head table, and called upon John H. Murdoch, Jr., Vice President of the American Water Works Service Co., Philadelphia, Pa., who presented a paper, entitled "Recruiting for Water Works."

May 1954 Meeting

Andover Country Club, Andover, Mass.

Thursday, May 20, 1954

The new Lawrence Experiment Station of the Massachusetts Department of Public Health and the Lawrence Water Filtration Plant were the objects of an inspection tour by many members and guests of the New England Water Works Association.

Luncheon was served at the Andover Country Club, after which President William B. Duffy introduced those at the head table and called upon the Mayor of Lawrence, Hon. John J. Buckley, and Sidney P. White of Andover, both of whom gave the group a most cordial welcome.

A paper, "Long-Range Planning for Andover Water Supply," was read by George A. Sampson, of Weston and Sampson, Boston, Mass.

A paper, "Operating Experience with Chlorine Dioxide," was read by Joseph C. Derby, Chief Chemist, Water Filtration Plant, Lawrence, Mass.

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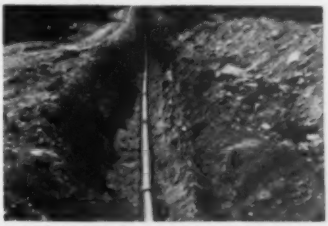

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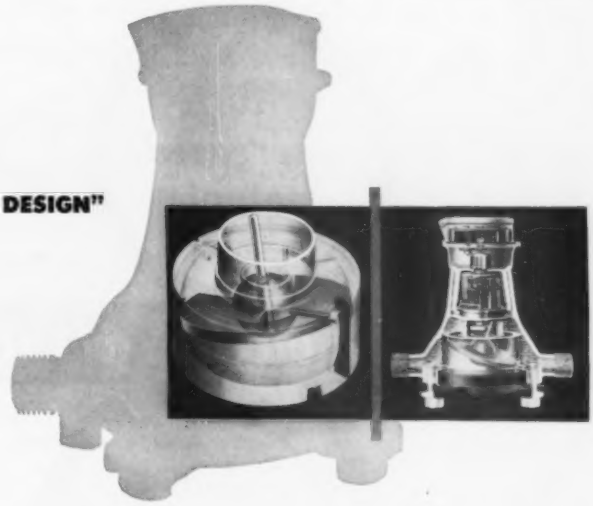

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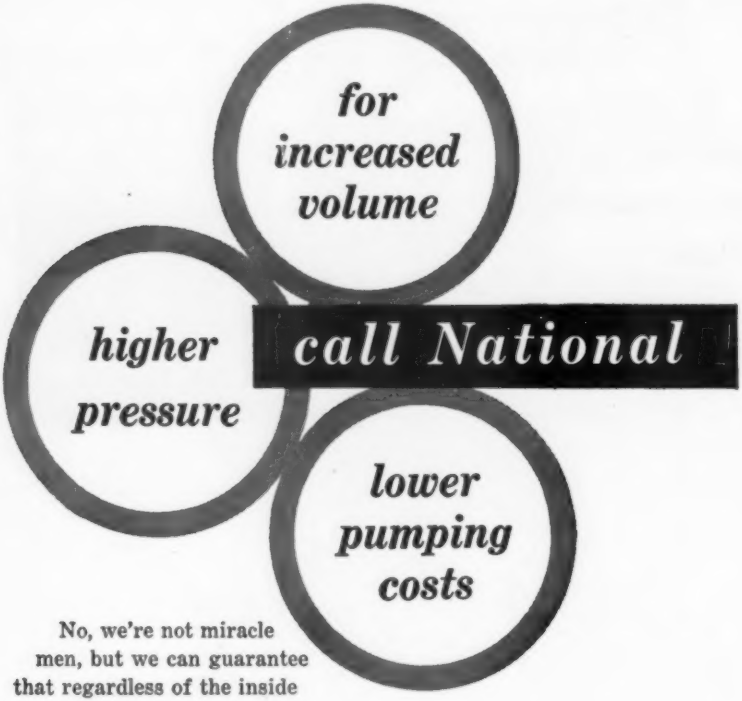

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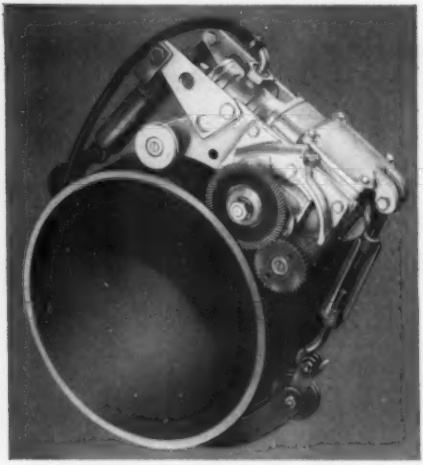

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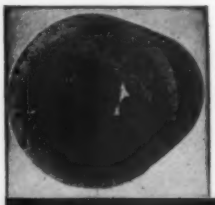

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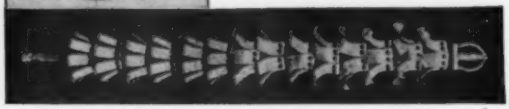

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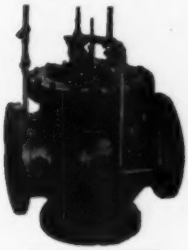

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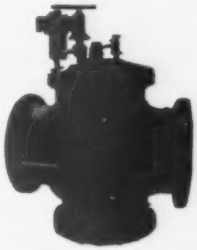

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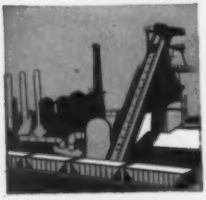

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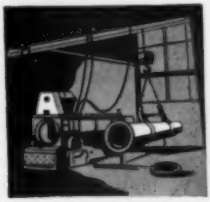

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